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Activity 6

The Evaluation of Autogenous and Semi-Autogenous Grinding of a Siliceous Ore

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ACTIVITY 6

The Evaluation of Autogenous and Semi-Autogenous Grinding of a Siliceous Ore

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ACTIVITY 6
THE EVALUATION OF AUTOGENOUS AND SEMI-AUTOGENOUS GRINDING OF A SILICEOUS ORE

ENERGY CONSERVATION
IN THE INDUSTRIAL MINERALS PROCESSING SECTOR
COMMINUTION (CRUSHING AND GRINDING) PHASE III
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1.2 Test Programme (con't)

A Hardinge 1830mm X 610mm Cascade mill was used for all tests. For configuration 1, wet autogenous grinding, the circuit was set up as shown in Figure 1.2-F1. The screen used was a 1220mm X 610mm Dillon Vibrating Screen with the oversize being returned to the mill.

For tests 5 to 9, the circuit was set up as shown in Figure 1.2-F2. A 915mm Diameter Hardinge Gyrotor was used as the air classifier, with a 1,524mm diameter cylcone to collect the fines. As the Gyrotor undersize closely matched the product specifications, it was collected as final product for these tests, with no material being returned to the mill.

Tests 10 to 11 were set up as shown in Figure 1.2-F3. For these tests, Gyrotor rejects were screened to improve the product size distribution with the screen oversize recirculated back to the mill.

For test 12, a 4% by volume (254 kg.) ball charge was added to the mill for a semi-autogenous grinding test. The grinding circuit configuration was similar to that for tests 10 and 11. (See Figure 1.2-F3)

A Wheelabrator Model 33 MPF dust collecter was used throughout the test programme to collect entrained fines in the airstream.

Screen analysis on all fractions were completed by conventional screening procedures. Minus 200 mesh material was analyzed with a Micromeritics Model 5000 ET Sedigraph Particle Size Analyzer.

1.3 Results and Conclusions

A summary of results is shown in Table 1.3-T1. The results of the Activity 6 Testwork indicates that a sand grade product was produced using autogenous grinding.

- The silica ore used for the grinding tests was amenable to wet and dry autogenous grinding as shown by the low recirculating loads on the grinding mill and the yield of final product of minus 65 mesh material present in the mill discharge.

- Dry autogenous grinding produced a coarse product and a higher product yield than wet autogenous grinding. This was an indication that classification was taking place in the mill. Particles in the minus 20 plus 65 mesh size range were being removed from the mill as soon as they were generated, thus not being ground further.

- Based on grinding mill energy requirements only, and new feed to the circuit, dry autogenous grinding required 37% less energy compared to wet autogenous grinding (3.3 kWh/tonne vs 5.3 kWh/tonne of new feed). However, using tonnes of final silica sand grade product as the measure of efficiency, dry autogenous grinding required 60% less energy than wet autogenous grinding (5.2 kWh/tonne vs 12.9 kWh/tonne product).

- Based on total grinding system energy requirements, including energy for the dry classification system and new feed to the circuit, wet autogenous grinding required 43% less energy than dry autogenous grinding (5.3 kWh/tonne vs 9.6 kWh/tonne of new feed). However, using tonnes of

1.0 EXECUTIVE SUMMARY

1.1 Objectives

A pilot scale test programme was operated at Witteck Development Inc. in Mississauga, Ontario to evaluate the use of autogenous grinding for Quartzite material from Steep Rock Resources to produce a coarse size (-20 +65 mesh) sand grade product.

The objectives of the programme were to compare data obtained from the following grinding and classification circuit configurations.

- Wet autogenous grinding in closed circuit with a classifying screen.
- Dry, swept autogenous grinding in closed circuit with a classifier and screen.
- Dry, air swept semi-autogenous grinding in closed circut with a screen and classifier.

1.2 Test Programme

The test programme for Activity 6 consisted of twelve tests, operated in one of the following configurations.

- Wet autogenous grinding with screening.
- Dry autogenous grinding and air classification and screening.
- Dry semi-autogenous grinding, air classification and screening.

silica sand grade product as the measure of efficiency, wet autogenous grinding required 13% less energy than dry autogenous grinding (12.9 kWh/tonne vs 14.9 kWh/tonne of final product). A portion of this energy saving would be used for classifying the wet autogenous mill discharge.

- The energy consumption during grinding for dry semi-autogenous grinding and dry autogenous grinding were similar based on per tonne of material treated. However, the comparison changes when energy for classification is included. Using total circuit energy data, dry semi-autogenous grinding shows a 22% saving in energy consumption per tonne of ore treated when compared with fully autogenous grinding (7.6 kWh/tonne vs 9.6 kWh/tonne). The relative saving is the same when energy consumptions are expressed on a per tonne of sand grade product basis (11.7 kWh/tonne vs 14.9 kWh/tonne).

- The production of minus 65 mesh material in the mill discharge suggested that classification taking place in the mill could be improved. It was observed during the test program that the fan was heavily loaded in removing the material from the mill.

- Increased fan capacity may have improved the product quality by removing the properly sized particles as soon as they were generated from the mill and reducing the amount of overgrinding taking place.

- The build-up of 25mm and 50mm material in the mill during the autogenous grinding testing indicated that the addition of steel grinding media for dry semi-autogenous grinding may have been beneficial. This was confirmed by a grinding test in which the use of dry semi-autogenous grinding increased throughput by 40% with a corresponding 20% decrease in power consumption compared to dry autogenous grinding.

- The wet autogenous grinding tests were carried out with a mill density of 65 to 70% solids. A decrease in the mill density may have reduced the amount of overgrinding that occurred during these tests.

- Dry semi-autogenous grinding showed the lowest energy consumption for the production per tonne of minus 20 plus 65 mesh coarse silica product.

- Further testwork is required to optimize the grinding conditions required to maximize the product yield and minimize power consumption required to grind silica ore. Wet semi-autogenous grinding should be considered for the production of silica sand.

- Chemical analysis of the feed and products indicated there was no concentration of deleterious substances in the product caused by the grinding system.

Table 1.3-T1

PROJECT 5174 - ACTIVITY 6

SUMMARY OF DATA

Date	Run No	Type	Screen	New Feed tonnes/hr	Product tonnes/hr	Product Size % -20	Product Size % -65	Tonnes/hr (-20+65)	Cascade Mill kWh (net)	Cascade Mill kWh Tonne (Feed)	Cascade Mill kWh Tonne (-20+65)	Cascade Mill P80 µm	Cascade Mill P80 µm	Cascade Mill Work Index	Fan kWh (net)	Fan rpm	Fan mm WC	Total kWh	Total kWh (Tonne) Prod	Total kWh Tonne Feed	Total kWh Tonne (-20+65)
Dec 17	1	Wet	6mesh	1.208	1.208	98	56	.51	6.98	5.78	13.68		295	10.5	-	-	-	6.98	5.78	5.78	13.68
Dec 18	2	Wet	10mesh	1.218	1.218	99	62	.46	7.17	5.90	15.76	101,000	280	10.4	-	-	-	7.17	5.90	5.90	15.76
Dec 19	3	Wet	10mesh	1.159	1.159	99	57	.49	7.07	6.11	14.48		300	11.2	-	-	-	7.07	6.11	6.11	14.48
Dec 22	4	Wet	6.4mm	1.167	1.167	99	57	.49	6.20	5.31	12.89		295	9.6	-	-	-	6.20	5.33	5.33	12.89
Jan 23	5	Dry	—	1.296	1.232	99	46	.66	4.65	3.59	7.05		340	7.0	5.23	3195	406	9.88	8.02	7.62	14.96
Jan 26	6	Dry	—	1.211	.978	99	52	.46	4.97	4.10	10.80		340	7.6	5.50	3195	406	10.47	10.71	8.65	22.76
Jan 28	7	Dry	—	1.176	1.098	99	49	.56	4.84	4.12	8.64		340	8.1	7.36	3550	508	12.20	11.11	10.37	21.79
Jan 30	8	Dry	—	1.135	1.068	99	52	.50	4.84	4.26	9.68		340	8.3	7.47	3550	511	12.31	11.52	10.85	24.62
Feb 3	9	Dry	—	1.187	1.120	99	56	.48	5.01	4.22	10.44	101,000	320	8.0	7.64	3550	515	12.65	11.29	10.66	26.35
Feb 13	10	Dry	—	1.292	1.187	100	30	.84	4.30	3.33	5.12		370	6.8	8.16	3550	520	12.46	10.49	9.64	14.85
Feb 15	11	Dry	—	1.381	1.276	100	38	.79	4.52	3.27	5.72		340	6.4	8.60	3550	515	13.12	10.28	9.50	16.61
Feb 19	12	Dry SAG	—	1.864	1.791	99	33	1.20	6.28	3.37	5.23		390	7.1	7.80	3550	515	14.08	7.86	7.55	11.73

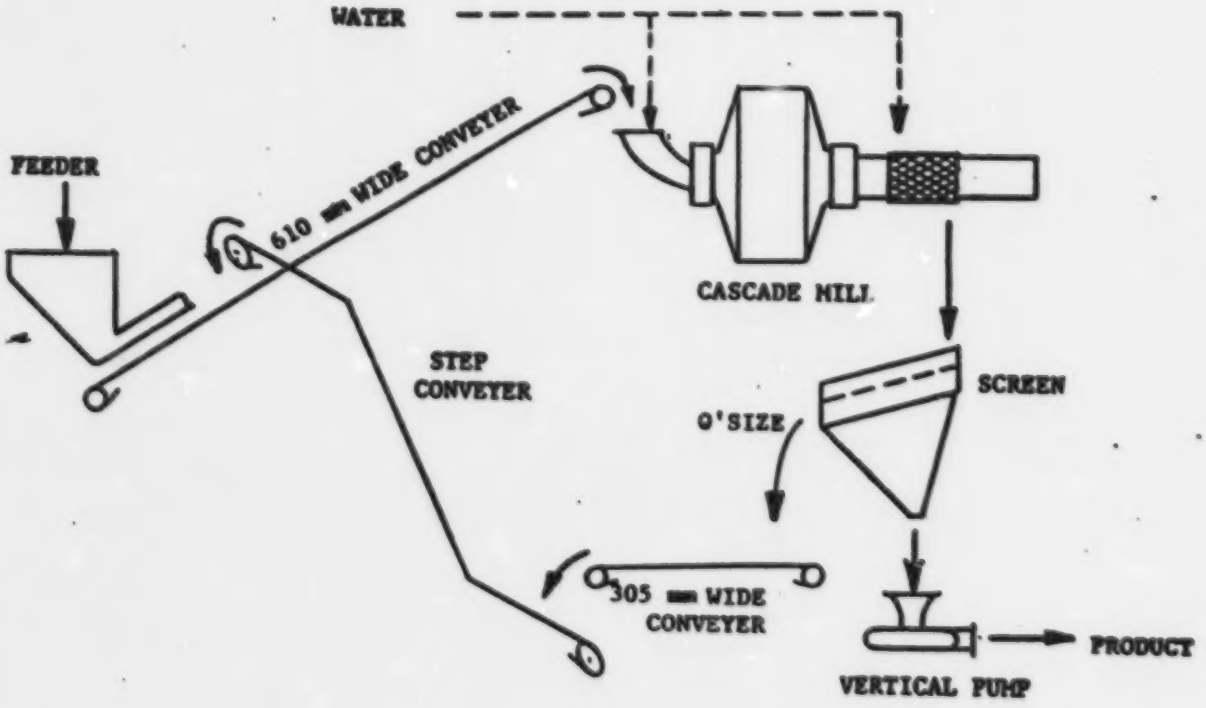
Figure 1.2 F1

DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

CIRCUIT CONFIGURATION

TESTS 1 - 4



WD1

Figure 1.2 - F2

DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS MILLING OF SILICA ORE CIRCUIT CONFIGURATION

TESTS 5 - 9

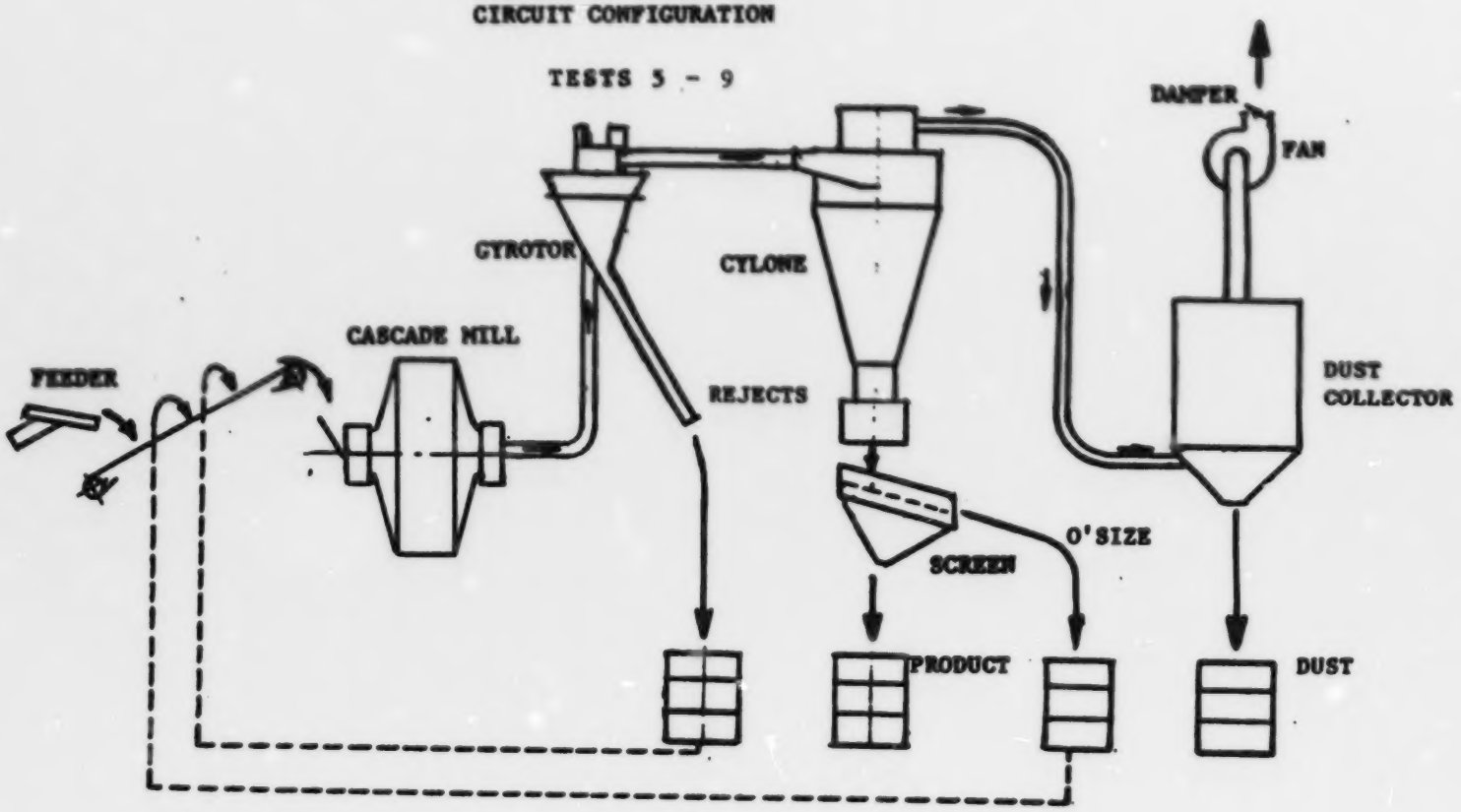


Figure 1.2 - F3

DSS-CANADA CEMENT LAFARGE

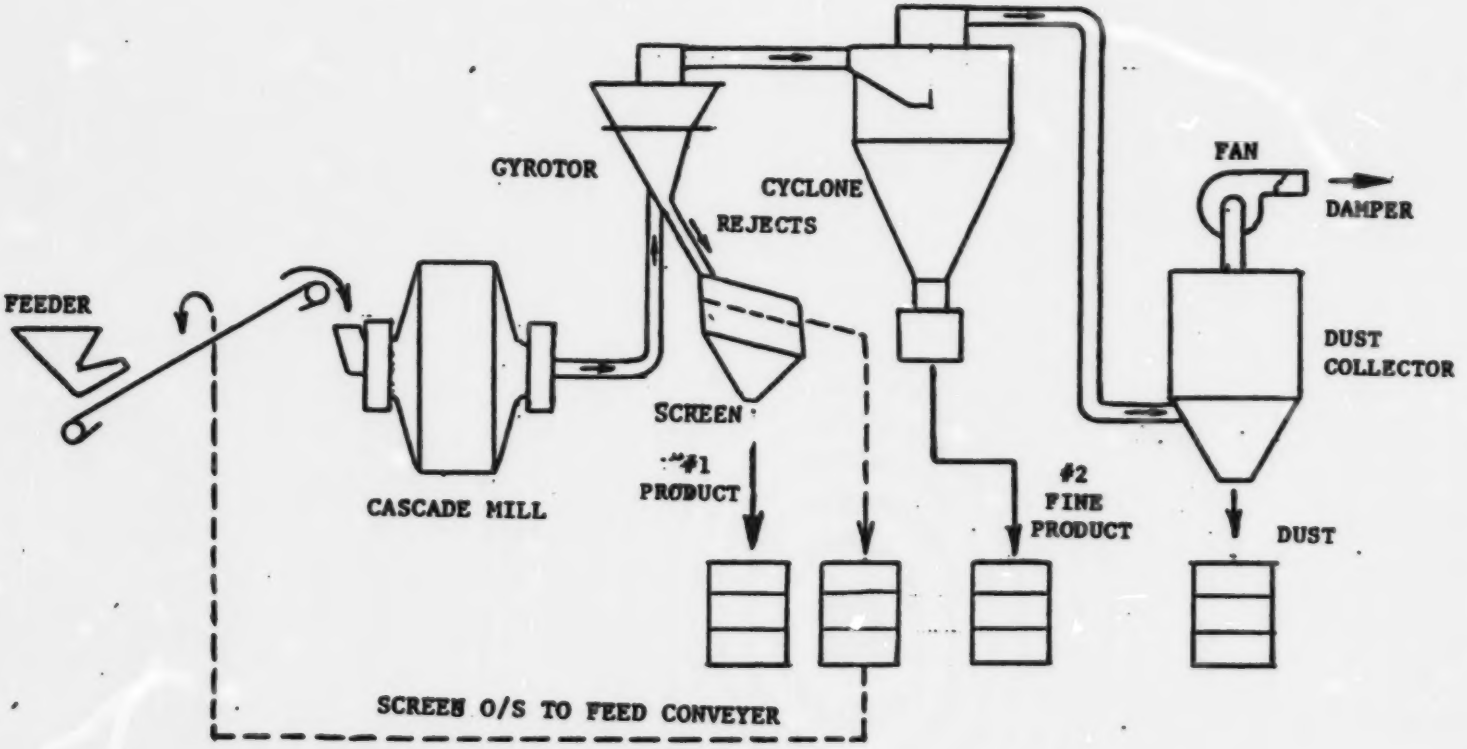
PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS

MILLING OF SILICA ORE

CIRCUIT CONFIGURATION

TEST 10 - 12



1.0 RESUME DU PROGRAMME DIRECTEUR

1.1 Objectifs

La société Witteck Development Inc. de Mississauga, en Ontario, a réalisé un programme d'essais, à l'échelle expérimentale, visant à évaluer l'utilisation du broyage autogène pour les matériaux quartzitiques de "Steep Rock Resources", afin d'obtenir un sable grossier (de granulométrie comprise entre moins 20 et plus 65 mesh).

Le programme a pour but la comparaison des données obtenues à partir des montages de l'équipement de broyage et de classification suivants:

- Broyage autogène par voie humide, en circuit fermé, avec crible-classeurs;
- broyage autogène ventilé à sec, en circuit fermé, avec classificateur et crible;
- broyage semi-autogène ventilé à sec, en circuit fermé, avec crible et classificateur.

1.2 Programme d'essais

Le programme d'essais concernant le plan d'activités No 6 comporte douze essais réalisés avec l'un des montages suivants :

- Broyage autogène par voie humide avec criblage;
- broyage autogène à sec, avec classification à l'air et criblage;
- broyage semi-autogène à sec, avec classification à l'air et criblage.

Un broyeur Cascade Hardinge, de 1830 x 610 mm, est utilisé pour l'ensemble des essais. Dans le montage No 1, broyage autogène par voie humide, l'équipement est installé conformément à la figure 1.2-F1. Le crible utilisé est un tamis vibrant Dillon, de 1220 x 610 mm) avec retour au broyeur des refus de crible.

1.2 Programme d'essais (suite)

Dans les essais Nos 5 à 9, l'équipement est installé comme indiqué à la figure 1.2-F2. On utilise un giratoire Hardinge de 915 mm de diamètre comme classificateur à air avec un cyclone de 1524 mm de diamètre, afin de recueillir les fines. Etant donné que les granulats trop petits produits par le broyeur giratoire sont conformes aux spécifications du produit, on les récupère comme produit fini lors des essais, sans retour au broyeur.

Les essais No 10 et 11 sont réalisés tel qu'indiqué à la figure 1.2-F3. Lors de ces essais, les résidus du broyeur giratoire sont passés au crible afin d'améliorer la granulométrie du produit, alors que les refus sont recyclés vers le broyeur.

Lors de l'essai No 12, on a ajouté au broyeur une quanité de boulets équivalant à 4% du volume soit (254 kg) afin d'effectuer un essai de broyage semi-autogène. Le montage de l'équipement de broyage est identique à celui utilisé pour les essais Nos 10 et 11 (voir figure 1.2-F3).

On utilise un collecteur de poussières Wheelabrator de modèle 33 MPF tout au long du programme d'essais afin de récupérer les fines entraînées dans la veine d'air.

L'analyse de toutes les fractions granulométriques est réalisée au moyen des méthodes conventionnelles de criblage. On analyse le produit de granulométrie inférieure à 200 mesh à l'aide d'un sédigraphe Micromeritics, modèle 5000 ET.

1.3 Résultats et conclusions

Le tableau 1.3-T1 donne un résumé des résultats du programme d'essais concernant le plan d'activités No 6. Ces résultats montrent qu'on a produit un granulat classé comme sable au moyen du broyage autogène.

- La silice utilisée lors des essais de broyage convient au broyage autogène à sec et au broyage autogène humide, comme l'indiquent les faibles charges de recyclage du broyeur et le débit de matière de granulométrie inférieur à 65 présent à la décharge du broyeur.

- Le broyage autogène à sec donne un granulat grossier à un débit plus élevé que le broyage autogène par voie humide. C'est l'indication qu'il se produit une classification dans le broyeur. Les granulats ayant une granulométrie comprise entre moins 20 et plus 65 mesh sont retirés du broyeur dès leur production afin qu'ils ne soient pas broyés de nouveau.

- En se basant seulement sur la demande en énergie du broyeur et de la nouvelle alimentation, le broyage autogène à sec nécessite 37% moins d'énergie que le broyage autogène par voie humide. (3,3 kWh/tonne de nouvelle alimentation contre 5,3). Toutefois, lorsque l'on utilise une quantité importante de produit fini d'un sable de silice pour mesurer l'efficacité, le broyage à sec nécessite 60% d'énergie de moins que le broyage autogène par voie humide (5,2 kWh/tonne de produit contre 12,9).

- En se basant sur les besoins en énergie de l'ensemble du sytème de broyage (y compris l'énergie nécessaire au système de classification à sec) et sur la nouvelle alimentation, on constate que le broyage en voie humide nécessite 43% moins d'énergie que le broyage en voie sèche (5,3 kWh/tonne de nouvelle alimentation, contre 9.6). Cependant lorsque l'on utilise une importante

1.3 Résultats et conclusions (suite)

quantité du produit fini d'un sable de silice pour mesurer l'efficacité, le broyage autogène en voie humide consomme 13% d'énergie de moins que le broyage autogène en voie sèche (12,9 kWh/tonne de produit fini contre 14,9). Une partie de l'énergie ainsi économisée serait utilisée pour la classification des produits à la décharge du broyeur autogène par voie humide.

- La consommation d'énergie requise pour le broyage semi-autogène à sec et le broyage autogène, par tonne de matérial traité, est similaire. Cependant ces données changent lorsque l'énergie requise pour la classification est prise en considération. Si l'on utilise les données du circuit entier, le broyage semi-autogène à sec consomme 22% de moins d'énergie, par tonne de minerai traité, que le broyage entièrement autogène (7.6 kWh/tonne vs 9.6 kWh/tonne). L'économie est la même lorsque les taux de consommation sont basés sur la tonne de sable fini (11.7 kWh/tonne vs 14.9 kWh/tonne).

- La production de granulats de moins 65 mesh dans la décharge du broyeur indique qu'il est possible d'améliorer la classification qui se produit dans le broyeur. On a observé, en enlevant les granulats du broyeur, que le ventilateur était très chargé.

- L'augmentation de la capacité du ventilateur peut avoir amélioré la qualité du produit en permettant d'enlever les particules de dimensions appropriées dès leur production, réduisant ainsi le surbroyage.

- L'accumulation dans le broyeur de produit de 25 et 50 mm au cours du broyage autogène indique que l'addition de boulets en acier lors du broyage semi-autogène à sec peut avoir été bénifique. Cette hypothèse s'est confirmée lors de l'essai de broyage durant lequel l'usage du broyeur semi-autogène a permis une augmentation de la capacité de 40% et une réduction correspondante d'environ 20% de la consommation d'énergie en comparaison avec le broyage à sec.

1.3 Résultats et conclusions (suite)

- Des essais de broyage autogène par voie humide furent réalisés avec une concentration en solides de 65 à 70% dans le broyeur. Une plus faible concentration de solides aurait peut-être réduit le volume de surbroyage au cours des essais.

- Les tests démontrent que le broyage semi-autogène à sec nécessite la plus faible consommation d'énergie pour la production par tonne de silice dont la granulométrie est de moins 20 à plus 65 mesh.

- Des essais complémentaires devront être réalisés afin d'optimiser le rendement et réduire la consommation d'énergie requise pour le broyage du minerai siliceux. Le broyage semi-autogène en voie humide devrait être envisagé pour la production du sable de silice.

- L'analyse chimique de l'alimentation et des produits indique que le broyage ne provoque aucune concentration de matières nocives dans le produit.

Tableau no1.3-T1

Projet 5174 - Plan d'activités no6

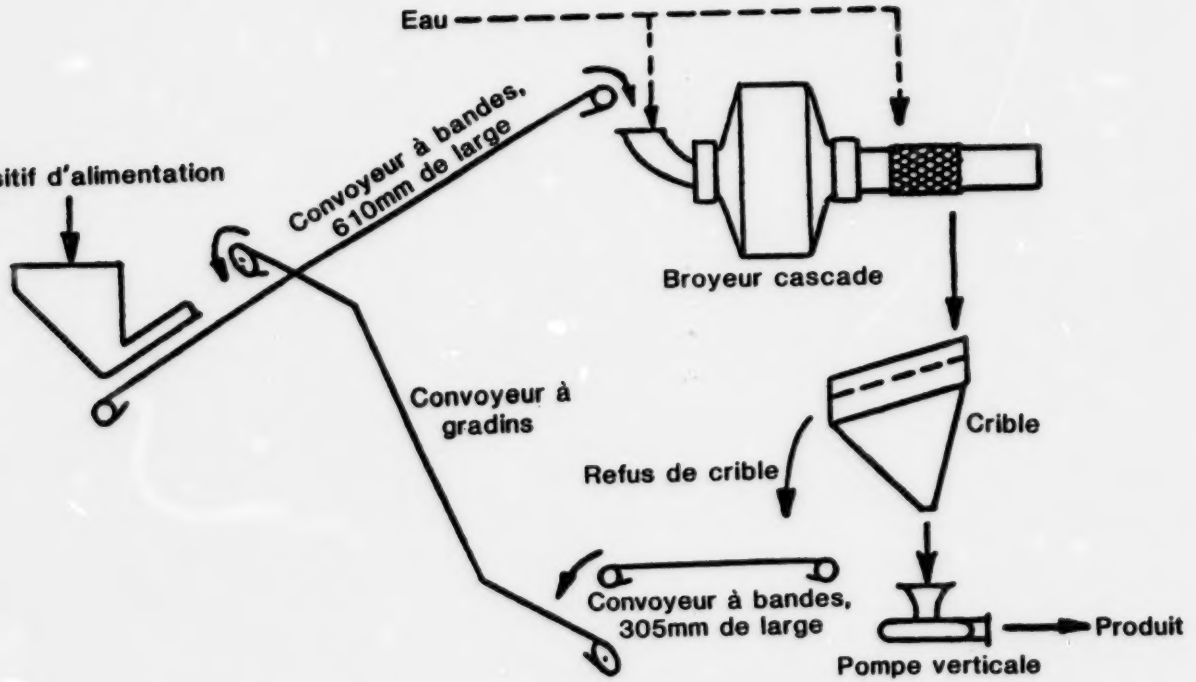
Relevé des données

Date	Essai no	Type	Crible	Nouvelle Alimentation	Produit (tonnes/h)	Calibre du produit		Tonnes/h (<20>65)	Broyeur cascade						Ventilateur			Total			
						%<20	%<65		kW-h (net)	kW-h tonne Aliment.	kW-h tonne (<20>65)	F80 um	P80 um	Rét. travail	kW-h (net)	t/min	mm WG	kW-h	kW-h (tonne) produit	kW-h tonne appro.	kW-h tonne (<20>65)
17 déc.	1	humide	6aeah	1.208	1.208	98	56	.51	6.98	5.78	13.68	101,000	295	10.5	-	-	-	6.98	5.78	5.78	13.68
18 déc.	2	humide	10aeah	1.218	1.218	99	62	.46	7.17	5.90	15.76		280	10.4	-	-	-	7.17	5.90	5.90	15.76
19 déc.	3	humide	10aeah	1.159	1.159	99	57	.49	7.07	6.11	14.48		300	11.2	-	-	-	7.07	6.11	6.11	14.48
22 déc.	4	humide	6.4mm	1.167	1.167	99	57	.49	6.20	5.31	12.89		295	9.6	-	-	-	6.20	5.33	5.33	12.89
23 jan.	5	séche	---	1.296	1.232	99	46	.66	4.63	3.59	7.05	101,000	340	7.0	5.23	3195	406	9.88	8.02	7.62	14.96
26 jan.	6	séche	---	1.211	.978	99	52	.46	4.97	4.10	10.80		340	7.6	5.50	3195	406	10.47	10.71	8.65	22.76
28 jan	7	séche	---	1.176	1.098	99	49	.56	4.84	4.12	8.64		340	8.1	7.36	3550	508	12.20	11.11	10.37	21.79
30 jan.	8	séche	---	1.135	1.068	99	52	.50	4.84	4.26	9.68		340	8.3	7.47	3550	511	12.31	11.52	10.85	24.62
3 fév.	9	séche	---	1.187	1.120	99	56	.48	5.01	4.22	10.44		320	8.0	7.64	3550	515	12.65	11.29	10.66	26.35
13 fév.	10	séche	---	1.292	1.187	100	30	.84	4.30	3.33	5.12		370	6.8	8.16	3550	520	12.46	10.49	9.64	14.85
15 fév.	11	séche	---	1.381	1.276	100	38	.79	4.52	3.27	5.72		340	6.4	8.60	3550	515	13.12	10.28	9.50	16.61
18 fév.	12	séche BSA	---	1.864	1.791	99	33	1.20	6.28	3.37	5.23		390	7.1	7.80	3550	515	14.08	7.86	7.55	11.73

Figure 1.2 – F1

DSS – CIMENTS CANADA LAFARGE

Projet 5174 Plan d'activités no6
Schéma de montage de l'équipement
Essais nos1 à 4



WD1

Figure 1.2 – F2

DSS – CIMENTS CANADA LAFARGE

Projet 5174 Plan d'activités no6
Schéma de montage de l'équipement
Broyeur autogène ventilé pour silice
Essais nos5 à 9

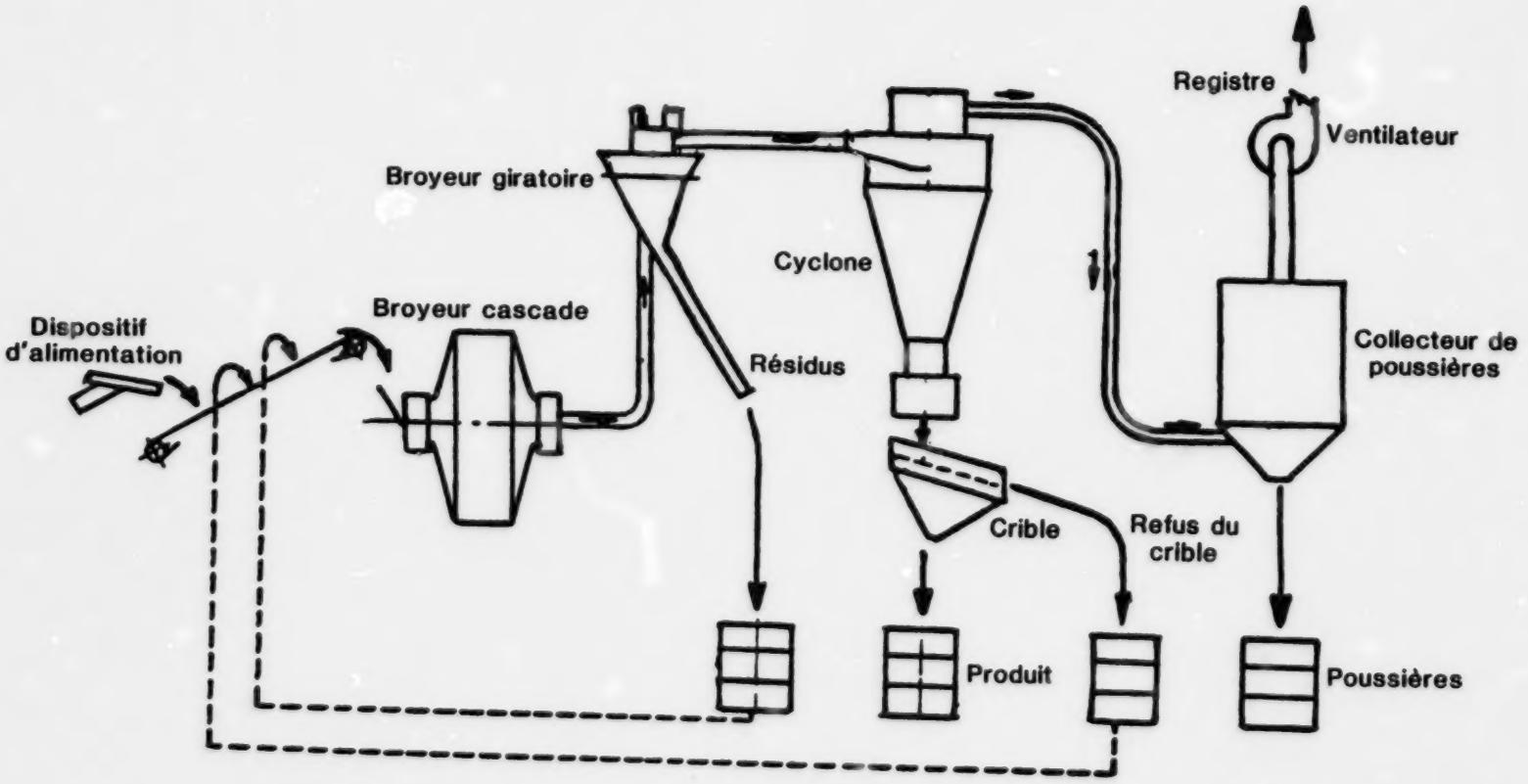
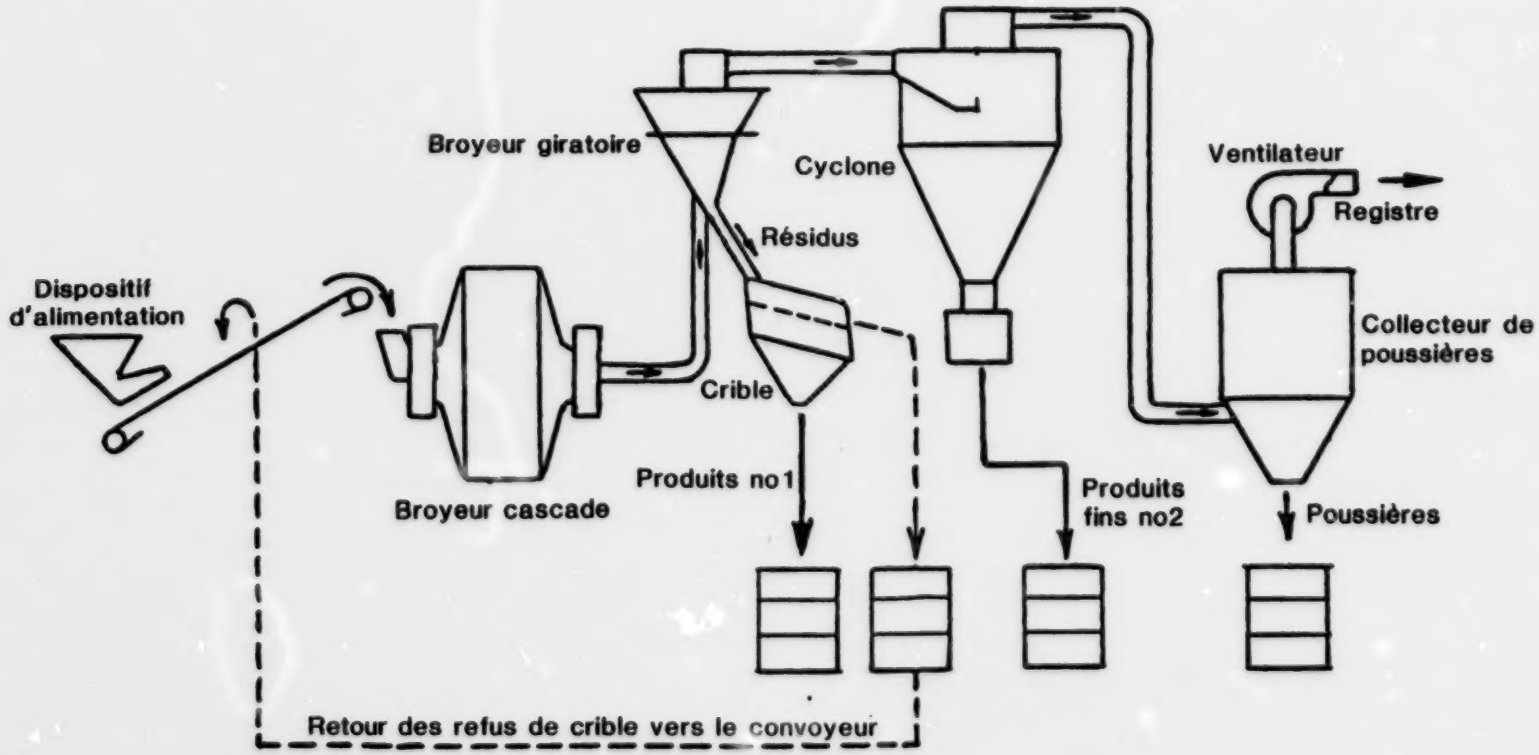


Figure 1.2 – F3

DSS – CIMENTS CANADA LAFARGE

Projet 5174 Plan d'activités no6
Schéma de montage de l'équipement
Broyeur autogène ventilé pour silice
Essais nos10 à 12



2.0 INTRODUCTION

The Canadian Industry Program for Energy Conservation (CIPEC) reported a 15% reduction in energy consumption per tonne of output in 1982, compared to the base year 1974. Much of this saving could be attributed to improved housekeeping. Achieving further conservation would require process modification and fuel switching; both require Research and Development (R&D). The areas for work were grouped as follows:

General R&D	applicable to industrial mineral processing in general
Cement R&D	processing of Portland and other hydraulic cements and gypsum plaster,
Clay Products R&D	applicable to manufacture of brick, tile pipe, etc.

The Department of Energy, Mines and Resources (EMR) CANMET, wishing to assist the industrial minerals processing sector in improving the energy efficiency of its operations, commissioned this study.

The overall objective as stated by EMR was,

> To develop the necessary technology to optimize the comminution of industrial minerals in terms of direct and indirect energy consumption.

EMR defined direct and indirect energy consumption in the following way.

> Direct energy consumption measures the work done during the crushing and grinding operations and is expressed in kWh/tonne.
>
> The indirect energy consumption is less frequently recognized and harder to quantify. Its effects are felt during secondary processing or utilization of comminuted materials. The correct size distribution of cement for example could command savings of up to 10% of the amount of cement necessary to make concrete. Optimization of comminution both in terms of kWh/tonne and in terms of processing energy consumption would make a major contribution to energy conservation in the industrial minerals processing sector.

Ten industrial minerals were chosen for study and, to achieve the objective, the work was divided by EMR into three phases.

Phase I Plant Studies to Develop a Data Base.

> For each mineral, studies were made of power consumption during comminution at a plant whose operations are typical of the industry. The results are from a brief investigation of the company's operations and therefore, are descriptive rather than analytical.

Phase II Establishment of Monitoring Methodology

> An evaluation was made of commercially available particle size measuring equipment with a view to establishing the feasibility of mill circuit control by on-line particle size measurements.

Also under this phase, a proposal for a pilot plant test program was developed.

Phase III Pilot Plant Studies of Comminution Related to Industrial Minerals and Energy Consumption.

This report is presented in accordance with Phase III, Activity 1 of the study on "Energy Conservation in the Industrial Mineral Sector - Comminution" for Canada Centre for Mineral and Energy Technology (CANMET), Energy, Mines and Resources Canada (EMR).

Witteck Development Inc. of Mississauga, Ontario, and I.M.D. Laboratories Ltd. of Toronto, are responsible for Activities 1, 2, 3, 4, 6 and 7 of the Phase III programme. The activities include the following:

Activity 1 Examination of the performance of a "state of the art" high efficiency classifier in a conventional milling circuit.

Activity 2 Examination, study and analysis of the state of development of classifiers for cement grinding circuits.

Activity 3 Examination of the use of grinding aids and anti-static agents in dry grinding circuits.

Activity 4 Monitoring and control of a dry grinding circuit using a particle size analyzer and programmable controllers.

Activity 6 Evaluation of the use of dry autogenous grinding of silica to produce coarse size sand grade product.

Activity 7 Development of the necessary technology to optimize the comminution of mica.

The objective of Activity 6 was to perform a series of autogenous and semi-autogenous mill tests to determine the conditions necessary to maximize recovery of a coarse size sand from silicious ore.

The work included autogenous and semi-autogenous air swept grinding as well as wet autogenous grinding. The pilot plant testwork was conducted between December 17, 1986 and February 19, 1987.

The test program included the following twelve runs.

Run No.	Description of Operation	Classification
1	Wet Autogenous	6 mesh screen
2	Wet Autogenous	10 mesh screen
3	Wet Autogenous	10 mesh screen
4	Wet Autogenous	6mm screen
5	Dry, Autogenous	Air Classifier
6	Dry, Autogenous	Air Classifier
7	Dry, Autogenous	Air Classifier
8	Dry, Autogenous	Air Classifier
9	Dry Autogenous	Air Classifier
10	Dry Autogenous	Air Classifier/14 mesh screen
11	Dry Autogenous	Air Classifier/20 mesh screen
12	Dry Semi-autogenous	Air Classifier/20 mesh screen

This report presents the results of the pilot plant testing at several levels of detail.

- A summary which contains the general description of the test programme, the general results and conclusions. The objectve of this part of the report is to give a general understanding of the test programme and the results without excessive detail.

- Detailed discussion which contains objectives, descriptions, results and conclusions of typical mill and classifier runs for each of the twelve campaigns.

- Working papers which are available for consultation. These papers contain complete results of laboratory and pilot plant tests including lab books, sedigraphs, recording charts, calculations and notes.

3.0 DESCRIPTION OF TEST EQUIPMENT

The following section describes the test equipment utilized for the Activity 6 test programmes. Figure 3.0-F1 illustrates the Wet Milling Circuit. Figure 3.0-F2 illustrates the Air Swept Milling Circuit used for Tests 5 to 9. Figure 3.0-F3 illustrates the Air Swept Milling Circuit used for Tests 10 to 12.

3.1 Mill

The mill utilized for the Activity 6 test programme was a 1830mm diameter by 610mm Hardinge Cascade mill equipped with 38mm x 76mm pebble ports which may be operated open or closed. The milling circuit may be operated fully autogenous, semi-autogenous, wet or dry. The mill had babbitted bearings and were continuously lubricated by a recirculating oil system with SAE 50 10W50 oil. The minimum oil viscosity was 700 SSU at 38°C with a minimum viscosity index of 100. The primary mill was equipped with two 2,200 to 3400 (kilograms) load cells located under the mill main frame. The main frame was supported by a lever support beam and the two load cells. The arrangement provided the best accuracy and sensitivity for monitoring mill load during the test runs.

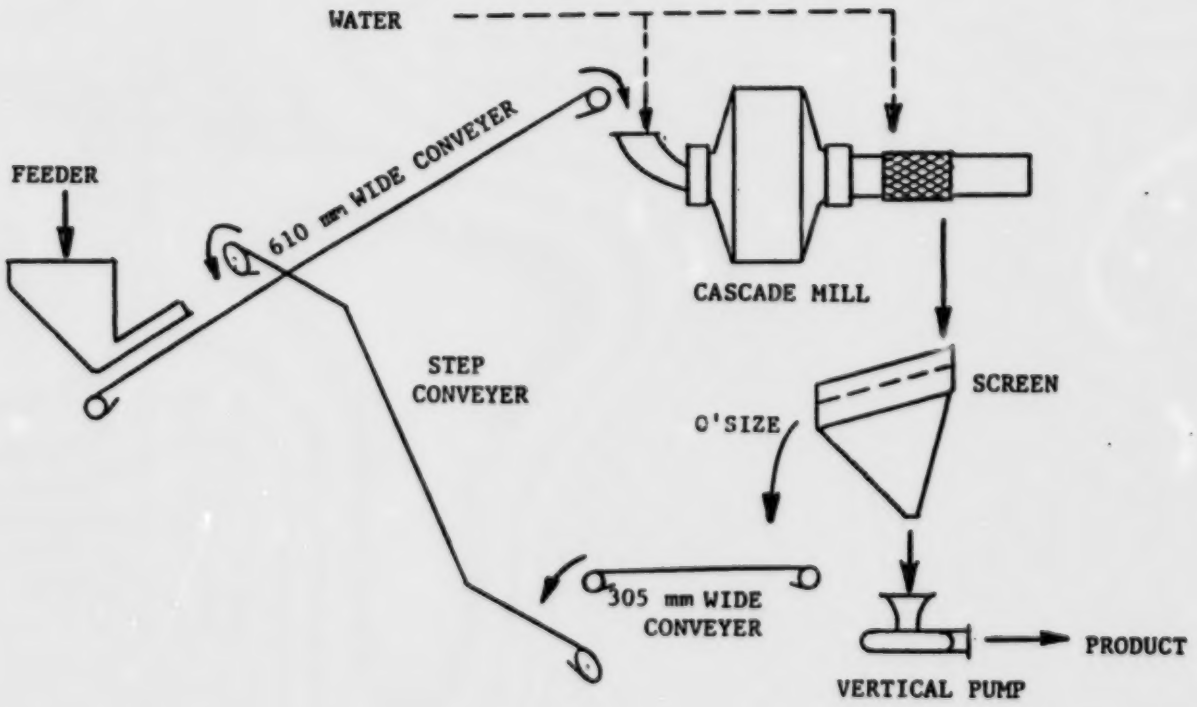
The Milltronics panel was equipped with two 2 channel chart recorders. Sound, weight and power was recorded on a continuous basis during each test run.

DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

CIRCUIT CONFIGURATION

TESTS 1 - 4



WD1

DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS
MILLING OF SILICA ORE
CIRCUIT CONFIGURATION

TESTS 5 - 9

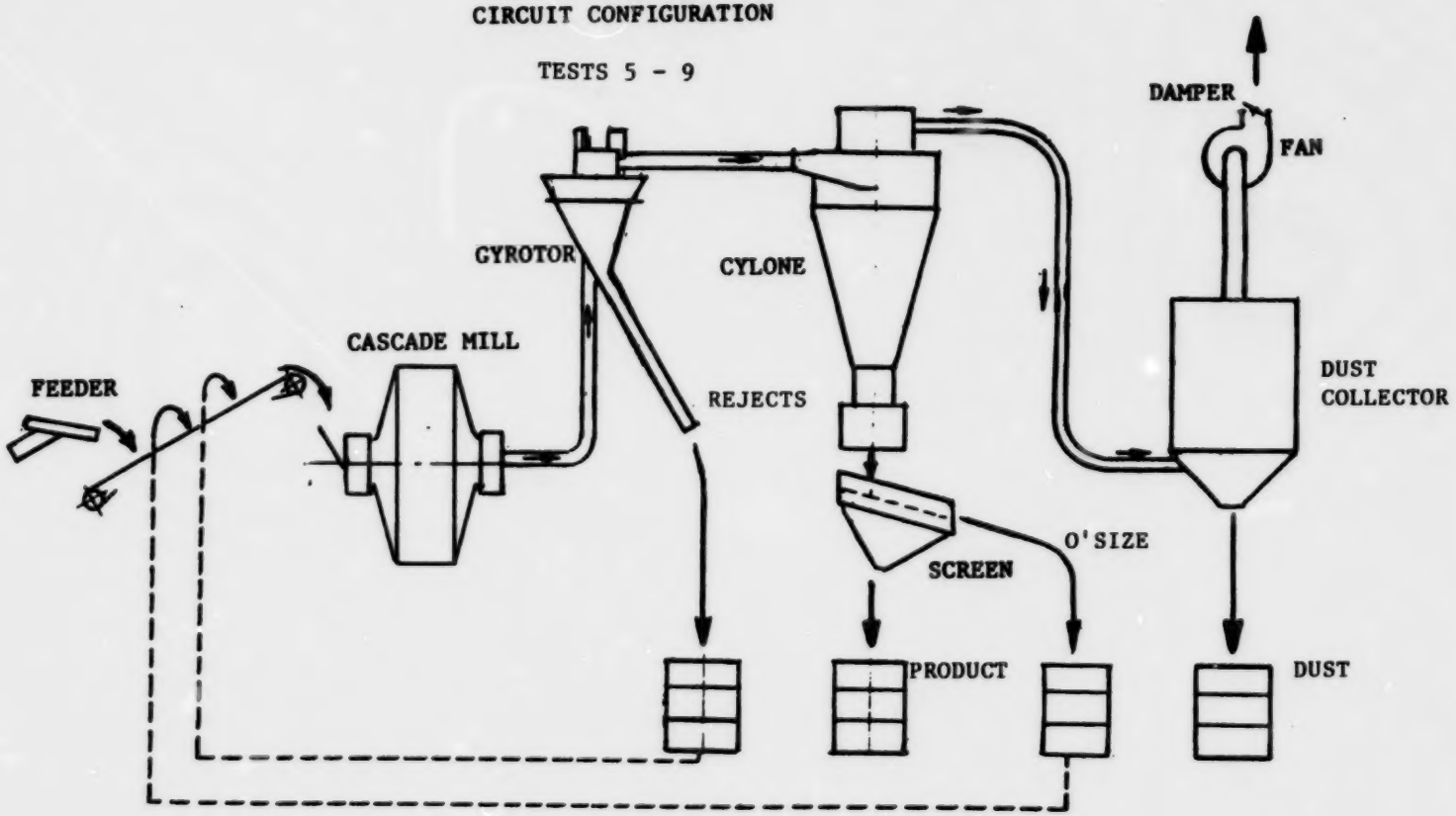


Figure 3.0 - F3

DSS-CANADA CEMENT LAFARGE

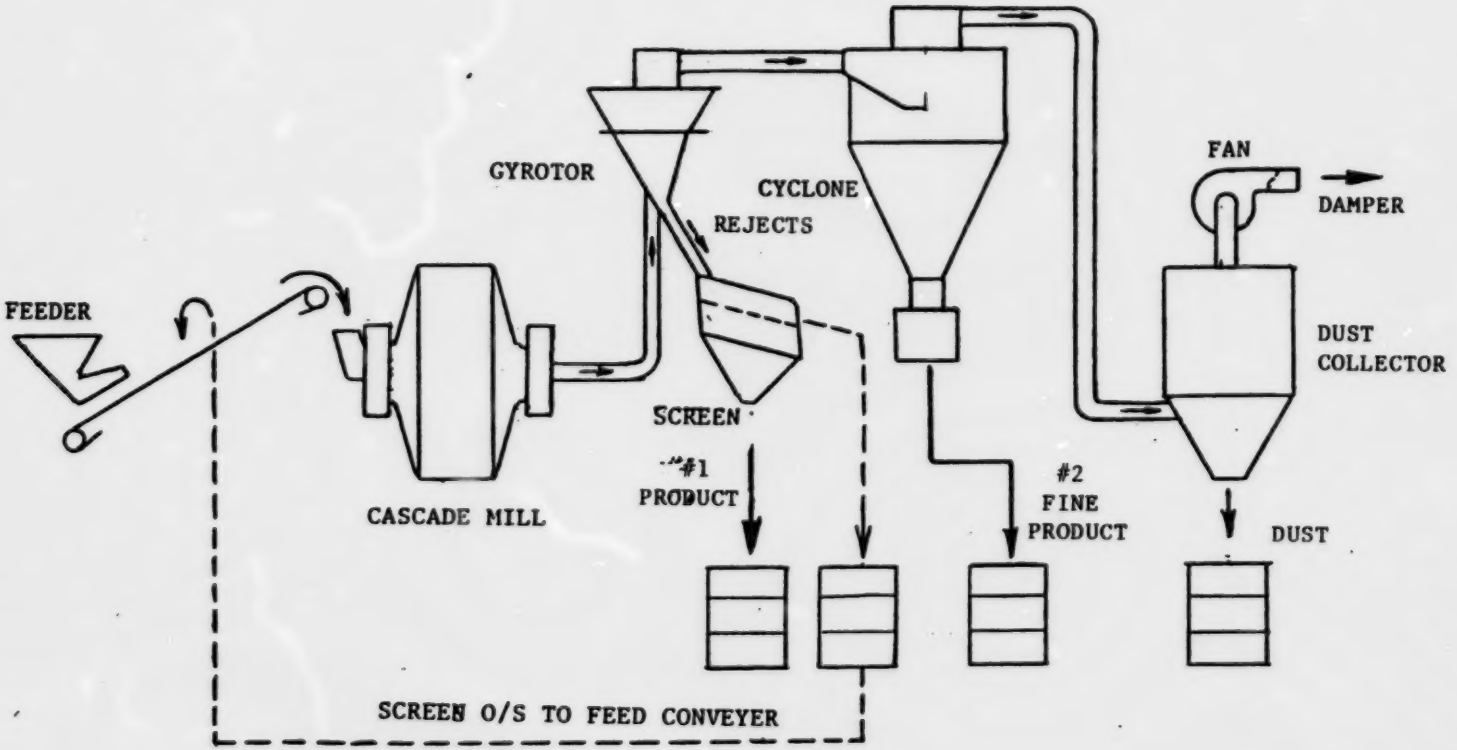
PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS

MILLING OF SILICA ORE

CIRCUIT CONFIGURATION

TEST 10 - 12



The test mill dimensions are presented in Table 3.1-T1.

Table 3.1-T1

MILL DATA FOR HARDINGE CASCADE MILL

DIAMETER BETWEEN LINERS	1760mm
DISTANCE FROM BOTTOM OF TRUNNION TO GRATE	620mm
MILL VOLUME	1.44 cubic meters
DISTANCE FROM BOTTOM OF MILL TO TRUNNION BOTTOM	600mm
ROTATIONAL SPEED	25 RPM
CRITICAL SPEED	78 percent

3.1.1 Mill Liners

The primary mill liners were fabricated from Nihard steel and each liner was held in place by four bolts. Lifters were 10mm wide, 3mm high and 38mm long. There were 16 liners/lifters installed in the mill.

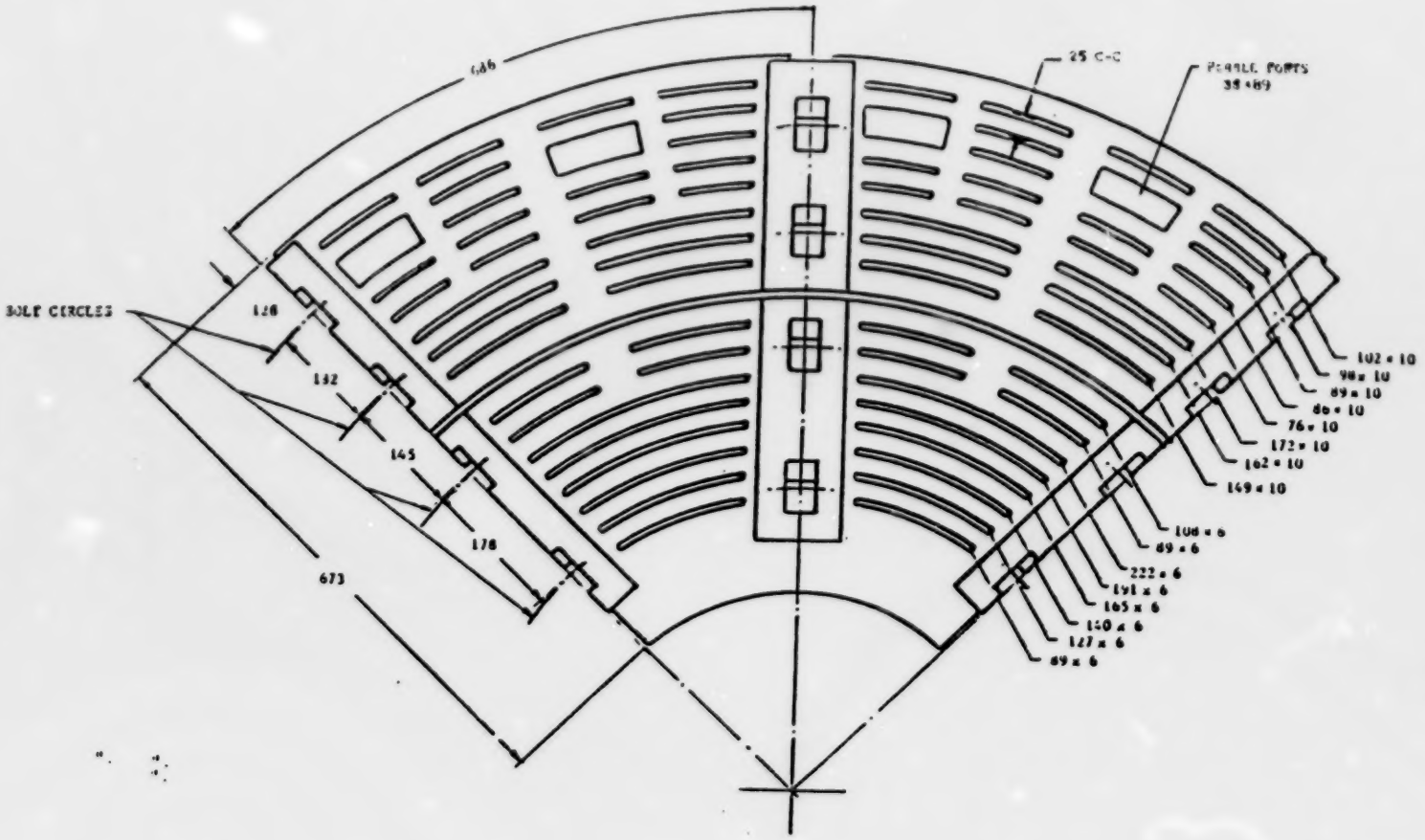
3.1.2 Mill Grating

The Cascade mill grating consisted of radial slots ranging in length from 76mm to 222mm long by 6 to 10mm wide. The discharge liner slots were spaced on 3mm center spacing as illustrated in Figure 3.3.-F1. Total open area of the grate was .33 square meters with the pebble ports open, .26 square meters with the ports closed.

3.1.3 Mill Drive

The Cascade mill was driven by a 25 horsepower electric motor (1200 rpm, 575 volt, 3 phase, 60 cycle) with a 3-belt drive driving a Falk gear reducer (reduction ratio - 13.9 to 1.0). The mill drive was driven from the gear reducer by a RC160 single width chain. The mill drive and power train had an overall mechanical/electrical efficiency of 84 percent.

FIGURE: 3.1.2 - F1



CASCADE MILL GRATE

3.1.4 Mill Feed System

Ore was handled from the coarse ore stockpile by a Clark Melroe Model 823 Bobcat front end loader. The front end loader was used to load the 5 tonne capacity feed hopper. A 610mm wide by 1830mm long Jeffrey vibrating feeder was used to feed the 610mm wide inclined troughing conveyor feeding the Cascade mill. The vibrating feeder was controlled manually by a variable frequency transformer and the load reading was taken from the Milltronics panel. The feed conveyor to the primary mill transported the feed and mill recycle material at a speed of 30.9 meters per minute. The feed rate to the mill was determined by weighing each loader bucket load and monitoring the time taken to feed the mill with the load.

3.1.5 Cascade Mill Discharge

The Cascade mill, when operated wet, was equipped with a trommel screen on the discharge which was 483mm diameter and 285mm long. The trommel was fitted with a 32mm square open screen. Two water sprays located on the inside of the trommel washed the mill product through the trommel at a controlled flow of 0 to 37.8 litres per minute. The trommel was equipped with a pebble extraction chute with 12mm high spiral for removing pebbles from the trommel when the mill pebble ports were open. The pebble extraction chute discharged into a diverter box capable of feeding the primary mill return conveyor or a jaw crusher transfer bin.

The Cascade mill, when operated dry, was equipped with 483mm diameter discharge tube. The discharge tube fitted into a vertically aligned aspirator. The mill was normally operated at approximately 28% volume. This corresponded to a load level about 50mm below the bottom of the trunnion.

3.2 Gyrotor Classifier

The classifier utilized in Activity 6 was a 915mm diameter Hardinge Gyrotor classifier. The classifier was complete with twelve rotor blades on even 30 degree centres constructed from 6.35mm thick carbon steel plate. The rotor speed was manually controlled by a gear reducer from 30-350 RPM. The maximum rotor tip speed was 1006 meters per minute. The average pressure differential across the classifier was 12.7mm (water column) at 38°C. The maximum design air flow for the classifier was 1.51 cubic meters per second (CMS) at 38°C.

3.2.1 Gyrotor Drive

The gyrotor was driven by a 1 1/2 H.P. 1800 rpm motor, (440 volts, 3 phase, 60 Hz). The motor was coupled to a 10:1 speed reducer via a Winsmith variable speed belt drive.

3.3 Cyclone Separator

A 1524mm dia. cyclone was used to collect dust during the air swept mill runs. The capacity of the cyclone was 56.6 cubic meters/min at 20°C with an average pressure drop of 76mm W.G.

3.4 Fan

The fan utilized for the Activity 6 test programme was a Buffalo Forge, Size 25 MV Centrifugal fan with straight paddle blades. The wheel diameter was 445mm. The outlet area was .052 square meters and the inlet area was .057 square meters. The fan was equipped with an extra heavy duty shaft and roller bearings for high speed operation.

3.4.1 Fan Drive

The fan was driven by a 20 H.P. Brooks electric motor (3440 rpm, 575 volts, 3 phase, 60 cycle) with a 3 belt drive to the fan. The fan drive had an overall electrical/mechanical efficiency of 86 per cent.

3.5 Dust Collector

The dust collector utilized in Activity 6 was a Wheelabrator Model MPF-Pulse Dust Collector, size No. 33 with 9 filter elements. The filter elements were 330mm diameter by 660mm long, multi-pleated, polyester type filters of 5 grams per square meter material. The unit was constructed of No. 12 gauge M.R.S. welded panels reinforced to withstand 380mm W.G. pressure. The rated capacity of the dust collector was 2.1 CMS, with gas temperatures ranging from $0^{o}C$ up to $135^{o}C$ maximum. The elements were cleaned by a pulse of reverse flow of air through the filters. The filters were cleaned on a row by row basis, three at a time, allowing continuous operation of the dust collector.

3.6 Screen and Oversize Return

The vibrating screen utilized for this activity was a Dillon 610 mm x 1220mm vibrating double deck screen. The screen operated at 21 degrees from horizontal. The vibrating frequency was 17.82 cycles per second. The top screen used was a 12.5mm square screen fabricated from 10 gauge steel wire. The bottom screen was changed between mill runs to establish the desired product and recirculating loads. For the wet milling tests, the screen oversize discharged onto a 400mm troughed belt conveyor operating at 610mm per second. The recirculating load to the mill was determined from 610mm belt cuts taken every fifteen minutes.

The belt conveyor discharged onto a pleated "step conveyor that transported the material at 56 degrees from horizontal to the cascade mill feed conveyor.

For the airswept runs, the screen oversize was fed to a bucket and was manually transferred to the mill feed conveyor every 12 minutes. The screen undersize was collected in 105 litre drums during these tests.

3.7 Power Measurement and Power Calculations

The gross milling power was monitored for both the mill and fan using individual General Electric Type V-62S two element power meters. A third power meter was used to monitor power for both mills and all auxiliary equipment associated with the circuit. The power meters were calibrated by Ontario Hydro to insure the rated accuracy of 1.5%. All power readings were measured in kilowatt-hours, then calculated to kilowatts using the time interval between meter readings. Corrected power was determined from input/output compounding energy data. The net power consumption was calculated based on the corrected gross power consumed by the drives as well as the bearings. The equations for determining the net power for the reading time interval [kW corr(t)] are:

kW corr(t) = [kW gross (t) - kW base (t)] X Eff

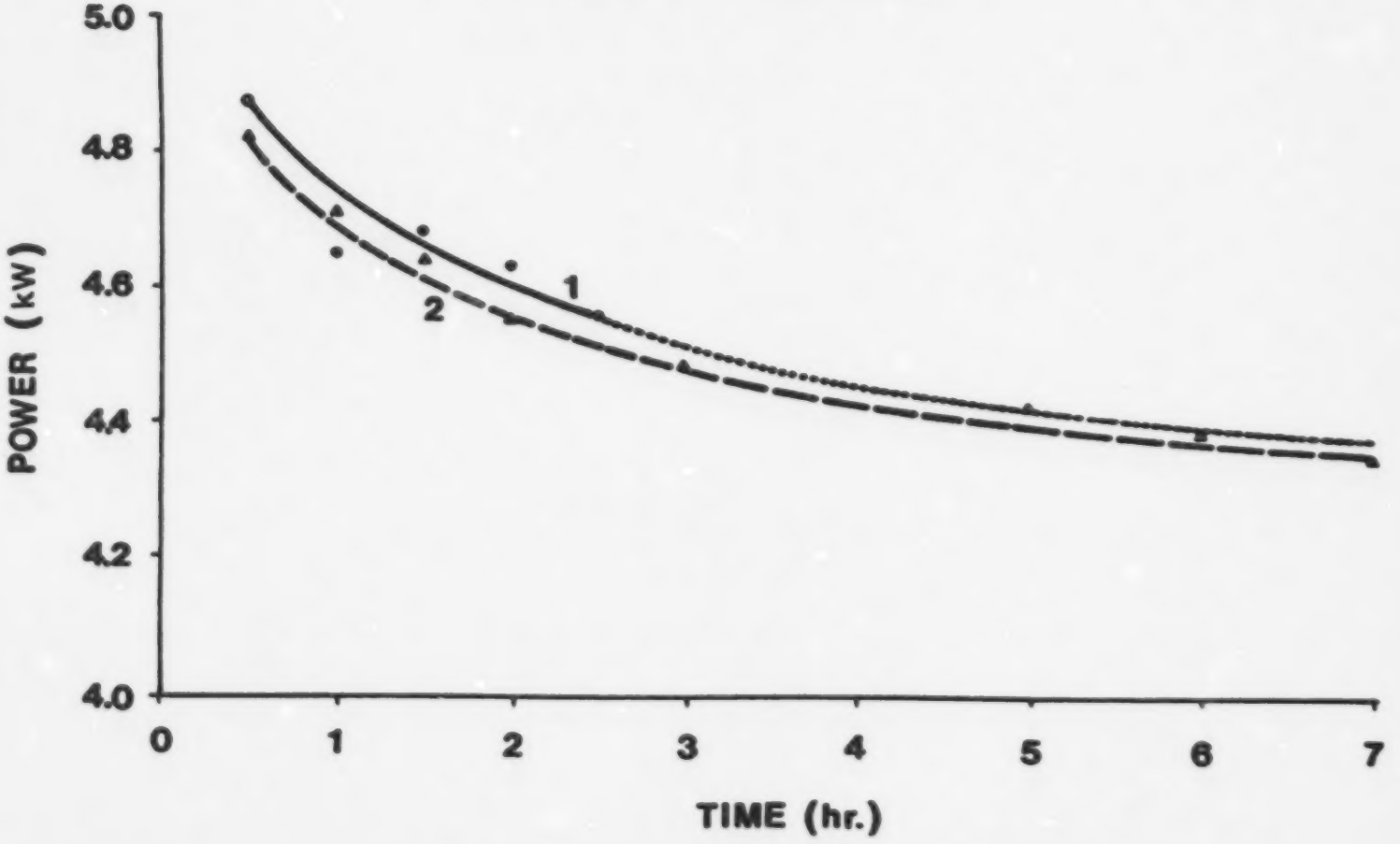
kW corr(t) = The corrected net power to the mill shell for a specific time interval (kilowatts).

kW gross(t) = The gross power measured by the power meter divided by the specific time interval (kilowatts).

kW base(t) = The average base power measured by the power meter during the two empty mill runs for the equivalent time duration. (kilowatts).

D.S.S.-CANADA CEMENT LAFARGE
ACTIVITY No.6

CASCADE MILL
BASELINE POWER DATA



Eff = The average efficiency of the mill power train.

Eff (mill) = 0.84

Eff (fan) = 0.86

At the start and finish of the test program, the mill was run empty and power readings were taken over a seven hour period. The average base power for the mill is illustrated in Figure 3.13-F1.

3.8 Grinding Rate

All grinding rate calculations were done on a dry feed basis. The grinding rate was determined using the weight of ore in each front-end loader bucket and the time to feed the entire bucket load to the mill. The primary mill load volume was maintained during each run at approximately 28 percent total mill volume (approximately 50mm below the feed trunnion). The mill load volume was maintained at this level by visual checks and by monitoring the total weight of the mill with the load cells.

3.9 Circulating Loads

Circulating loads were calculated on a dry feed basis and expressed as a ratio of the dry mill feed rate. The circulating load for the mill circuit was was determined by weighing 610mm long cuts taken from the recirculating belt conveyor every 15 minutes. The corrected dry weight was then multiplied by the conveyor belt speed. The circulating load for the air swept mill was determined by weighing a timed sample from the screen oversize before it was transformed to the feed conveyor.

3.10 Product Rates

The product rate was calculated on a dry basis and was determined by weighing the individual drums in which the various product fractions were collected and the operating time of the circuit.

4.0 TEST PROCEDURES

4.1 General

The test program for Activity 6 consisted of 12 separate mill runs, operated in one of the following configurations.

1. Wet Autogenous Grinding
2. Dry Autogenous Grinding and Classification
3. Dry Semi-autogenous Grinding and Classification.

4.2 Sample Receiving

The Steep Rock quartzite ore arrived at Witteck Development in three 26 tonne dump-trucks. The total weight of the ore was 107 tonnes and was stored outdoors. Approximately 5 to 15 tonnes of ore were moved inside the building at least one day before each run.

4.3 Head Sampling

Ore head sample was obtained by mounting a 560mm wide bucket on the front-end loader and taking samples at 2 metre intervals around the perimeter of the ore pile. Care was taken not to bias the sample with the coarse material on the outside of the pile. The head sample obtained was screened from 127mm to minus 200 mesh.

4.4 Wet Autogenous Milling

Four wet autogenous milling tests were conducted on the Steep Rock Quartzite. The circuit was operated as illustrated in Figure 3.0-F1. The circuit consisted of the Cascade mill equipped with a trommel screen, a vibrating screen and two return conveyors to the mill. The pebble ports were closed for the first two tests, and opened for the last two tests. Undersize from the screen was pumped to a 9 cubic meter waste bin. Samples of the screen undersize were taken every 12 minutes. The head sample size distribution was representative of the feed material.

The mill charge was dumped and screened upon completion of the last test. The results of these tests are discussed in Section 5.3 of this report.

4.5 Air Swept Autogenous Milling

Seven air swept autogenous milling tests were conducted on the Steep Rock silica ore. The circuit consisted of the Cascade mill, Gyrotor classifier, cyclone, vibrating screen, dust collector and fan. Five tests were conducted using the circuit configuration as illustrated in Figure 3.0-F2. Two tests were conducted using the circuit configuration as illustrated in Figure 3.0-F3. The samples for the different product fractions were taken as grab samples from each column as the drum was replaced under its respective discharge point.

The head sample size distribution was assumed to be representative of the feed material. The mill charge was dumped and screened upon completion of the mill runs.

4.6 Air Swept Semi-Autogenous Milling

One test was performed utilizing the circuit as illustrated in Figure 3.0-F3, with a 254 kg ball charge added to the mill. This corresponded to a 4% by volume ball charge and was made up of 127 kg of 102mm balls and 152 kg of 76mm balls. Sampling procedures for this test were similar to that as described in Section 4.5.

The head sample size data was assumed to be representative of the feed material. The mill charge was dumped and screened upon completion of this run.

4.7 Screen and Particle Size Analysis

Screen analysis on all fractions were completed by standard metallurgical procedures. Minus 200 mesh material was further analyzed with a Micromeritics Model 5000 ET Sedigraph Particle Size Analyzer.

4.8 Clean Up and Disposal

The products from the test milling circuit were allowed to settle in one of two 9 cubic metre waste bins. The water was allowed to drain from the bins before being emptied. A backhoe was used to transfer the drained product from the bins to a tandum dump truck. The product was hauled and dumped in the Mississauga Britania Road Landfill Site. Products from the air-swept runs were placed in 210 litre drums and transferred to the 9 cubic meter waste bins with a Bobcat front-end loader.

4.9 Product Assays

Feed and all product fractions from a wet autogenous grinding test, dry autogenous and dry semi-autogenous grinding tests were assayed by atomic adsorption for seven elements. The elements assayed were Si, Fe, Mn, Al, Cu, K and Na. A mass balance of each element was completed to determine if any product upgrading or contamination occurred during the milling and classification of the silica.

These assays showed no build up of iron or other deleterious elements in the products caused by the grinding process.

4.10 Airborne Dust Assessment

Since silica is a designated substance under the Ontario Occupational Safety and Health Act, respirators were worn by all personnel involved with the testwork during the dry grinding tests. An independent organization was brought in to perform an industrial hygiene survey and assess personnel exposure to airborne alpha quartz silica during milling operations. The report is presented in Appendix II.

Table 4.9-T1

WET AUTOGENOUS GRINDING

	Assay %							
	SiO	Fe_2O_3	MnO	Al_2O_3	CaO	K_2O	Na_2O	Total*
Feed	95.9	0.22	0.007	1.33	0.95	1.52	0.022	100.0
Product	95.9	0.22	0.007	1.33	0.95	1.52	0.022	100.0

DRY AUTOGENOUS GRINDING

	Assay %							
	SiO	Fe_2O_3	MnO	Al_2O_3	CaO	K_2O	Na_2O	Total*
Feed	95.8	0.23.	0.006	1.58	0.98	1.40	0.029	100.0
Product	95.9	0.21	0.006	1.42	0.87	1.57	0.029	100.0
Dust Coll. Product	79.6	0.61	0.026	6.01	6.04**	7.66	0.051	100.0
Cyclone Product	90.8	0.46	0.013	3.44	2.34	2.87	0.032	100.0

DRY SEMI-AUTOGENOUS GRINDING

	Assay %							
	SiO	Fe_2O_3	MnO	Al_2O_3	CaO	K_2O	Na_2O	Total*
Feed	95.4	0.23	0.008	1.82	0.98	1.55	0.029	100.0
Product	95.3	0.29	0.007	1.72	0.90	1.80	0.029	100.0
Dust Coll. Product	76.3	1.03	0.051	6.18	8.66**	7.70	0.057	100.0
Cyclone Product	89.6	0.53	0.015	4.10	2.39	3.36	0.037	100.0

* Assay may not total 100.0% due to round off error.

** Sample may be contaminated with CaO from Activity 1 calcite testwork.

1018A

WD1

5.0 PILOT PLANT TEST RESULTS

5.1 Head Analysis

The size distribution of the Steep Rock quartzite ore is presented in Table 5.1-T1. The size distribution curve for this data is presented graphically in Figure 5.1-F1. Based on this screen distribution, the F80 size for the Steep Rock quartzite is 101,000 microns.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. N/A
DATE: DEC. 16,1986

HEAD SAMPLE

MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	28.50	9.34	9.34	90.66
4"	101	35.00	11.48	20.82	79.18
3"	76	71.00	23.28	44.10	55.90
2"	50.8	47.00	15.41	59.51	40.49
1"	26.7	43.50	14.26	73.77	26.23
3/4"	19.7	0.00	0.00	73.77	26.23
1/2"	12.6	15.50	5.08	78.85	21.15
1/4"	6.4	14.00	4.59	83.44	16.56
6	3.3	4.35	1.43	84.87	15.13
8	2.4	2.06	.68	85.54	14.46
10	1.7	1.14	.37	85.92	14.08
14	1.2	.80	.26	86.18	13.82
20	.833	.84	.28	86.46	13.54
28	.589	.94	.31	86.76	13.24
35	.420	12.90	4.23	90.99	9.01
48	.295	2.80	.92	91.91	8.09
65	.208	15.80	5.18	97.09	2.91
100	.147	2.15	.70	97.80	2.20
150	.105	2.56	.84	98.64	1.36
200	.074	2.40	.79	99.42	.58
-200		1.76	.58	100.00	0.00
TOTAL		305.00	100.00		

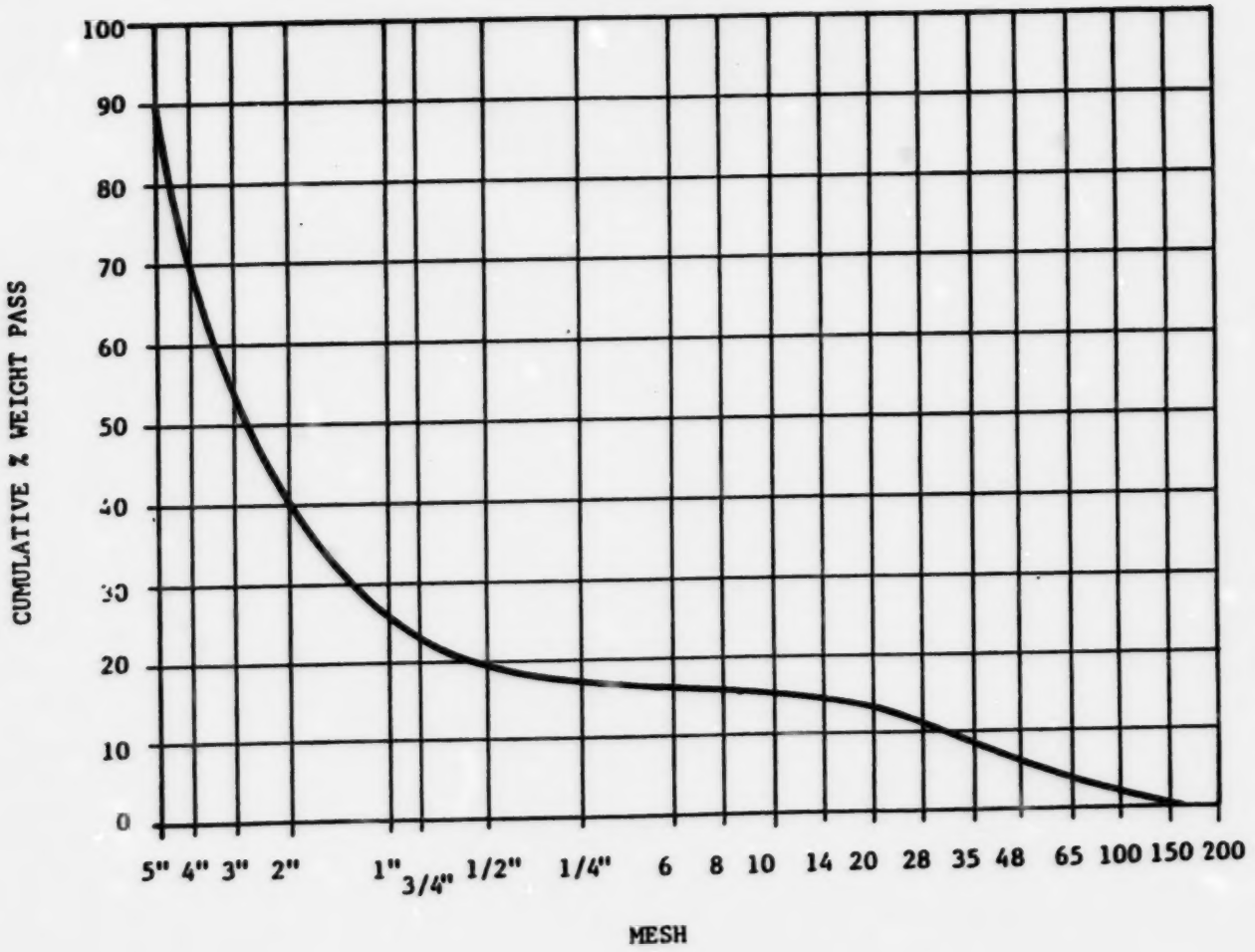
Figure 5.1-F1

DSS - CANADA CEMENT LAFARGE

AUTOGENOUS MILLING OF SILICA ORE

PROJECT No.5174

HEAD SAMPLE SIZE DISTRIBUTION



5.2 Wet Autogenous Milling Shakedown Results

SHAKEDOWN RESULTS

Purpose: Fully autogenous primary, wet milling using Steep Rock Quarzite ore.

Descripiton: The test was started with an empty mill and run fully autogenous. Primary classification was achieved with a 610mm x 1220mm Dillon screen. A 20 mesh single deck screen was used. The mill load was monitored with the load cells and displayed in the Milltronics panel and recorded on a Strip chart. The mill was stopped intermittently to visually note the charge level in the mill. Once the proper level was established (approximately 50mm below the trunion for a 28% by volume load), the vibrating feeder was turned off and on at short intervals to maintain a constant load in the mill.

The summary of results are presented in Table 5.2-T1

Table 5.2 T-1

SUMMARY OF TEST RESULTS

Shakedown

TYPE OF RUN	Wet Autogenous Grinding
% MOISTURE IN ORE	3%
DRY FEED TO MILL	3542 kg
OPERATING TIME	2 hours, 39 minutes
AVERAGE PRODUCT RATE	1337 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	340 microns
CIRCULATING LOAD	NA

NO LOAD POWER (DRAW)	4.95 kWh
AVERAGE POWER DRAW	12.5 kWh
AVERAGE POWER AT MILL SHELL	7.55 kWh
NET POWER CONSUMPTION	5.64 kWh/tonne
WORK INDEX (TONNE)	NA

5.3 Wet Autogenous Milling Results

5.3.1 Run No. 1

Purpose: The purpose of this test was to run the mill wet fully autogenous to produce a 100% minus 20 mesh plus 65 mesh material from the Steep Rock quartzite.

Description: The test was started with a fully loaded mill (28% by volume). Flow rates, per cent solids and power readings were taken every 15 minutes. Samples for screen analysis were taken every 12 min. after the system had reached steady state.

Classification: 610mm x 1220mm Dillon screen with a 6 mesh screen. The summary of results is presented in Table 5.3.1-T1

The size distribution from the screen undersize (product) is presented in Table 5.3.1.-T2.

The size distribution curves are shown in Figure 5.3.1-F1.

The mass balance flow diagram is presented in Figure 5.3.1-F2.

Table 5.3.1-T1

SUMMARY OF TEST RESULTS

Run No. 1

TYPE OF RUN	Wet Fully Autogenous
% MOISTURE	6%
DRY FEED TO MILL	3718 kg
OPERATING TIME	3 hours, 5 minutes
AVERAGE PRODUCT RATE	1208 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	295 microns
CIRCULATING LOAD	13%
% SOLIDS DISCHARGE	68%

NO LOAD POWER DRAW	3.76 kWh
AVERAGE POWER DRAW	10.74 kWh
MILL POWER TRAIN EFFICIENCY	85%
AVERAGE POWER AT MILL SHELL	6.98 kWh
NET MILL POWER CONSUMPTION	5.78 kWh/tonne
WORK INDEX (TONNE)	10.5

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 1
DATE: DEC. 17,1986

FINAL PRODUCT

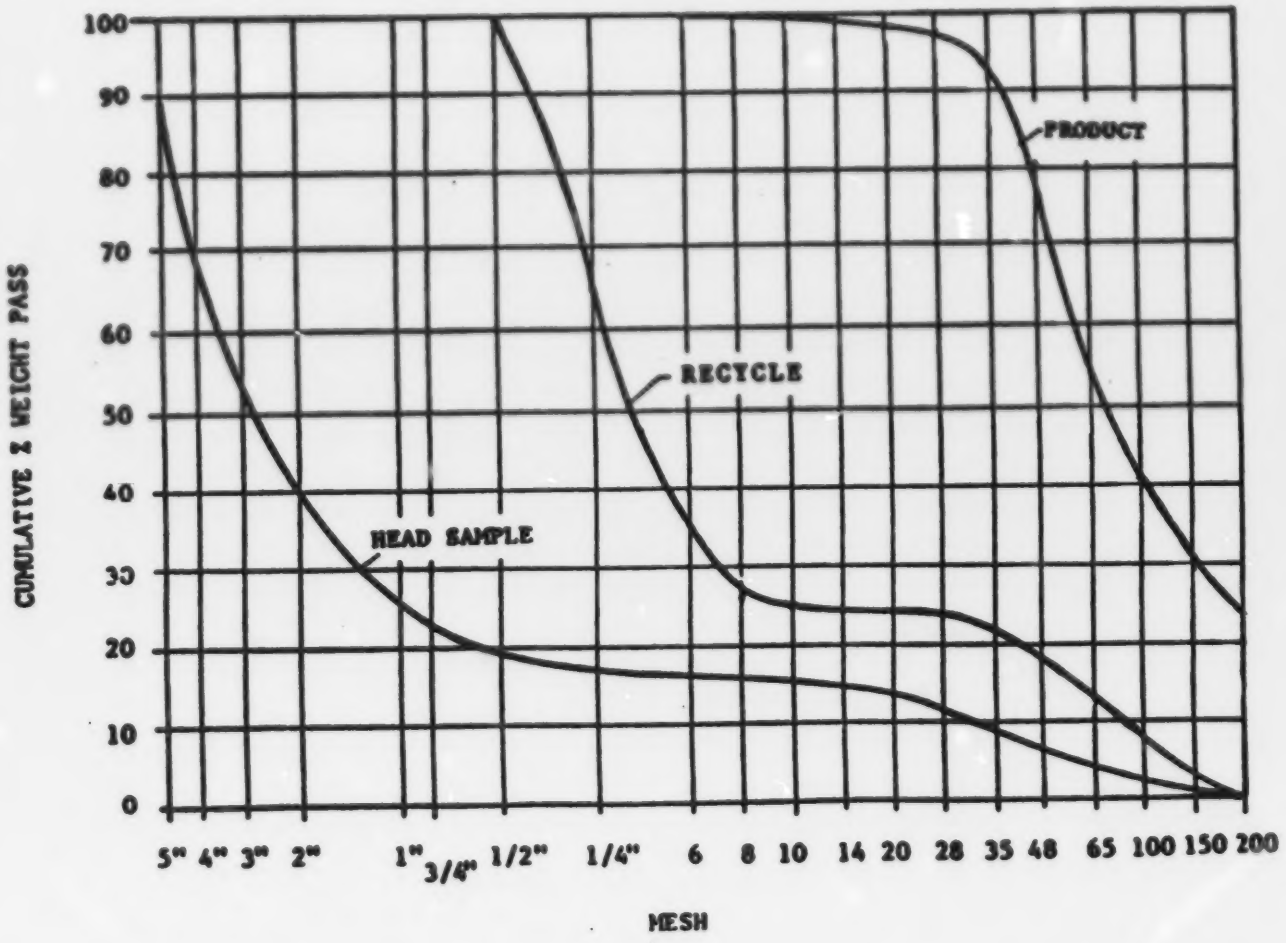
MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	.30	.04	.04	99.96
8	2.4	2.20	.28	.32	99.68
10	1.7	3.80	.49	.82	99.18
14	1.2	3.60	.47	1.28	98.72
20	.833	3.80	.49	1.77	98.23
28	.589	8.10	1.05	2.82	97.18
35	.420	43.20	5.60	8.42	91.58
48	.295	96.30	12.47	20.89	79.11
65	.208	179.40	23.24	44.13	55.87
100	.147	117.90	15.27	59.40	40.60
150	.105	70.70	9.16	68.55	31.45
200	.074	54.60	7.07	75.62	24.38
-200		188.20	24.38	100.00	0.00

DSS - CANADA CEMENT LAFARGE

5.3.1-F1

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.1

PRODUCT SIZE DISTRIBUTION



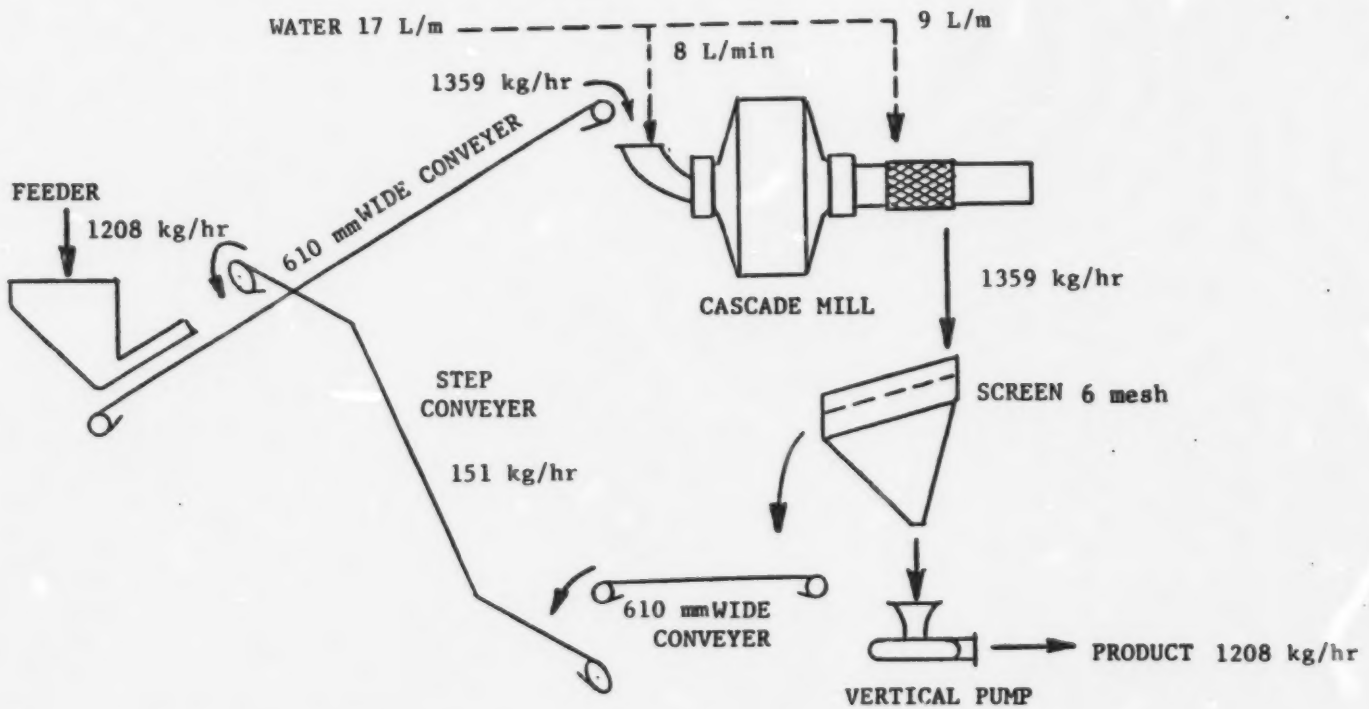
WDI

DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

CIRCUIT CONFIGURATION

RUN No. 1



5.3.2 Run No. 2

Purpose: The purpose of this test was to run the mill wet fully autogenous to produce 100% minus 20 mesh plus 65 mesh product from the Steep Rock quartzite ore. A 10 mesh screen was used to monitor the effects on the recirculating load and the final product.

Description: The test was run for 3 hours with no mechanical or technical problems. The circuit throughput and circulating load remained relatively unchanged from the previous run.

Classification: 610mm x 1220mm Dillon screen with a 10 mesh screen. The summary of results is presented in Table 5.3.2-T1.

The size distribution for the screen undersize (product) is presented in Table 5.3.2-T2.

The size distribution curves are shown in Figure 5.3.2-F1.

The mass balance flow diagram is presented in Figure 5.3.2-F2.

Table 5.3.2-T1

SUMMARY OF TEST RESULTS

Run No. 2

TYPE OF RUN	Wet Fully Autogenous
% MOISTURE	6%
DRY FEED TO MILL	3666 kg
OPERATING TIME	3 hours, 3 minutes
AVERAGE PRODUCT RATE	1218 kg/hr
HEAD F 80	101,000 microns
PRODUCT P 80	280 microns
CIRCULATING LOAD	14%
% SOLIDS DISCHARGE	67%

NO LOAD POWER DRAW	4.48 kWh
AVERAGE POWER DRAWS	13.02 kWh
MILL POWER TRAIN EFFICIENCY	85%
AVERAGE POWER @ MILL SHELL	7.17 kWh
NET POWER CONSUMPTION	5.90 kWh/tonne
WORK INDEX (TONNE)	10.4

SIZE DISTRIBUTION

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 2
DATE: DEC. 19,1986

FINAL PRODUCT

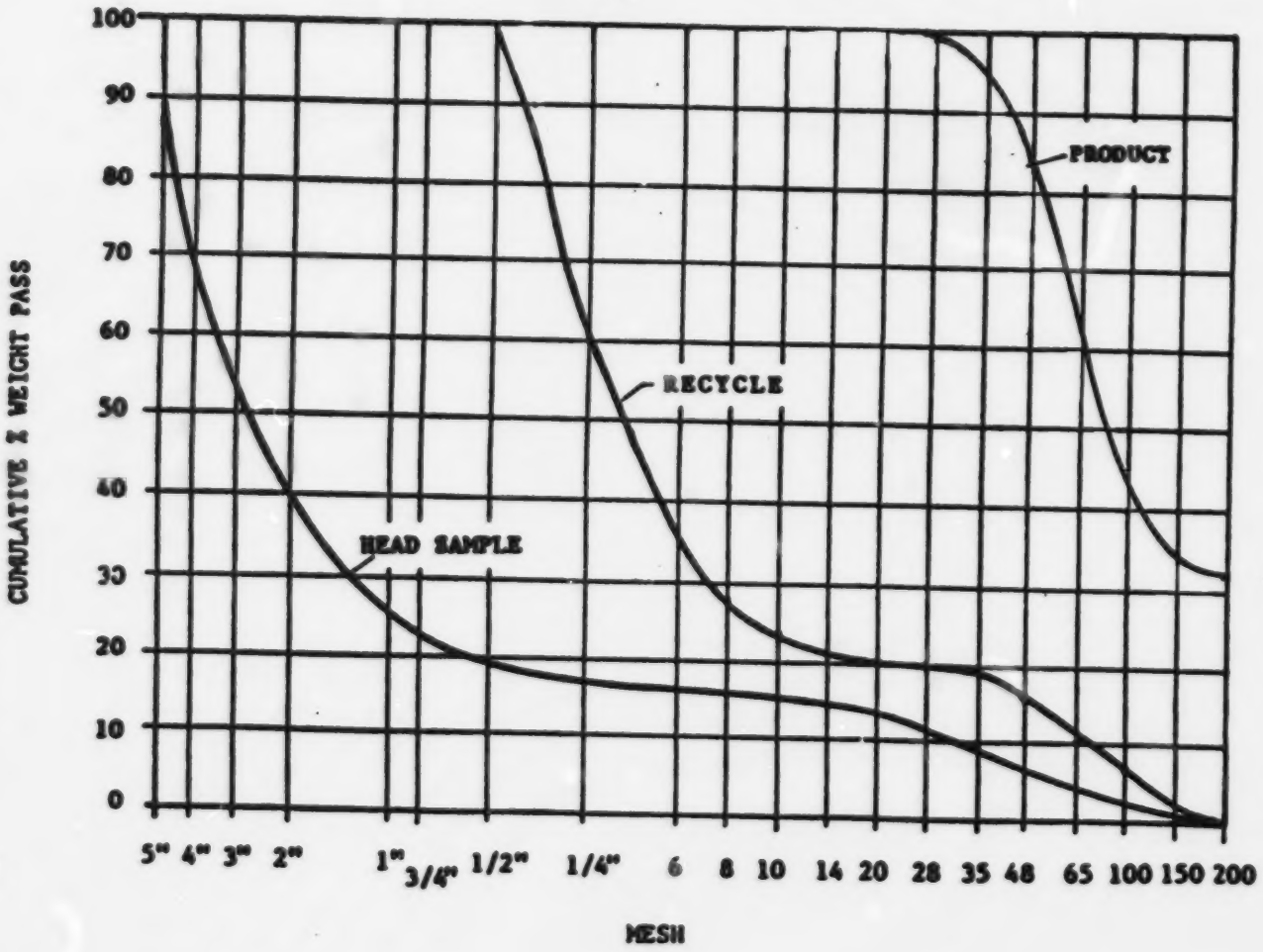
MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	0.00	0.00	0.00	100.00
10	1.7	0.00	0.00	0.00	100.00
14	1.2	1.00	.14	.14	99.86
20	.833	2.10	.29	.42	99.58
28	.589	4.20	.57	.99	99.01
35	.420	32.20	4.38	5.38	94.62
48	.295	80.00	10.89	16.27	83.73
65	.208	158.30	21.55	37.82	62.18
100	.147	126.80	17.26	55.08	44.92
150	.105	76.80	10.45	65.53	34.47
200	.074	20.80	2.83	68.36	31.64
-200		232.40	31.64	100.00	0.00
TOTAL		734.60	100.00		

DSS - CANADA CEMENT LAFARGE

5.3.2-F1

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.2

PRODUCT SIZE DISTRIBUTION



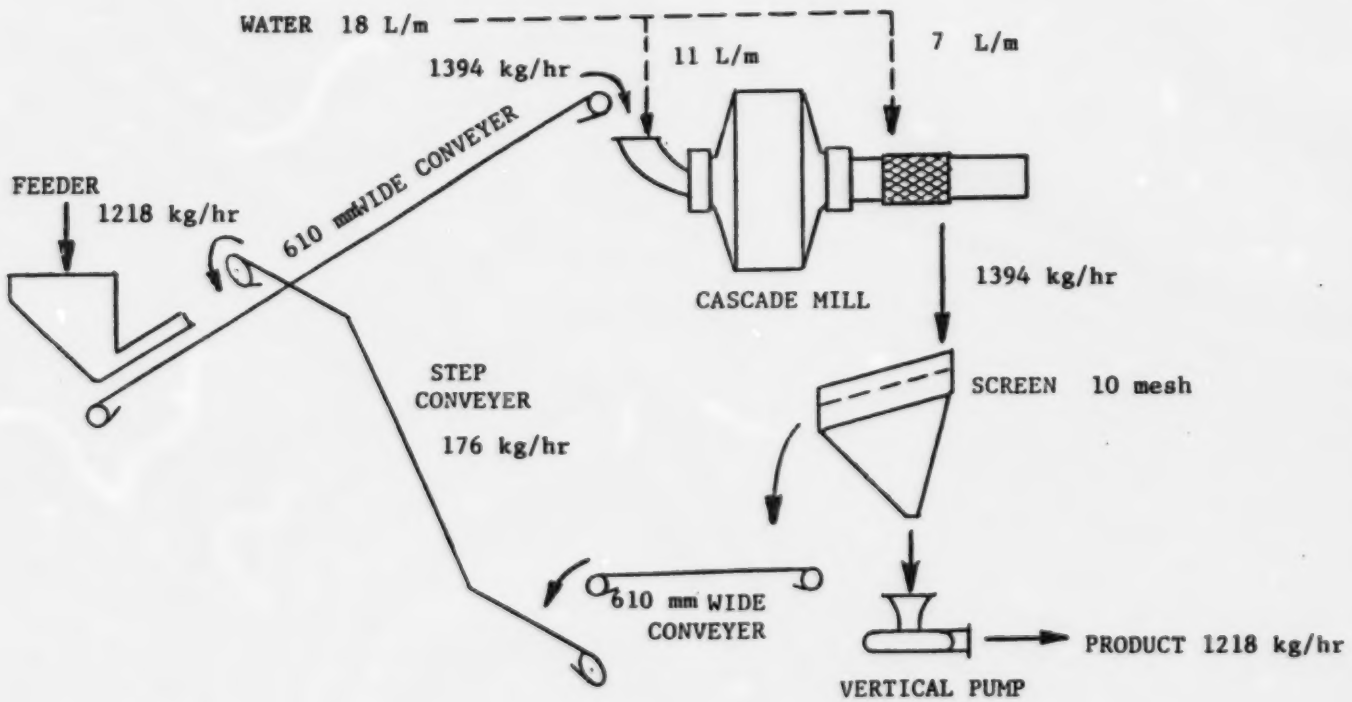
WD1

DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

CIRCUIT CONFIGURATION

Run No. 2



5.3.3 Run No. 3

Purpose: The purpose of this test was to run the mill wet fully autogenous to produce a 100% minus 20 mesh plus 65 mesh material. The pebble ports were opened to monitor the effects on the recirculating load and the final product.

Description: The test was started with a fully loaded mill and run for three hours with no technical difficulty. The pebble ports were opened resulting in an increase of the recirculating load (from 15% to 38%) but had little effect if any on the size distribution of the final product. Pebbles accounted for approximately 60% of the recirculating load.

Classification: 610mm x 1220mm Dillon screen with a 12.5mm top deck and a 10 mesh bottom deck screen. The summary of results is presented in Table 5.3.3-T1.

The size distribution from the screen undersize is presented in Table 5.3.3-T2.

The size distribution curves are shown in Figure 5.3.3-F1.

The mass balance flow diagram is presented in Figure 5.3.3-F2.

Table 5.3.3-T1

SUMMARY OF TEST RESULTS

Run No. 3

TYPE OF RUN	Wet Fully Autogenous
% MOISTURE	10%
DRY FEED TO MILL	3488 kg
OPERATING TIME	3 hours, 3 minutes
AVERAGE PRODUCT RATE	1159 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	300 microns
TOTAL CIRCULATING LOAD	38.5%
PEBBLES	24.5%
SCREEN O/S	14%
% SOLIDS DISCHARGE	66%

NO LOAD POWER DRAW	4.48 kWh
AVERAGE POWER DRAW	12.90 kWh
MILL POWER TRAIN EFFICIENCY	85%
AVERAGE POWER @ MILL SHELL	7.07 kWh
NET POWER CONSUMPTION	6.11 kWh/tonne
WORK INDEX (TONNE)	11.2

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 3
DATE: DEC. 19,1986

FINAL PRODUCT

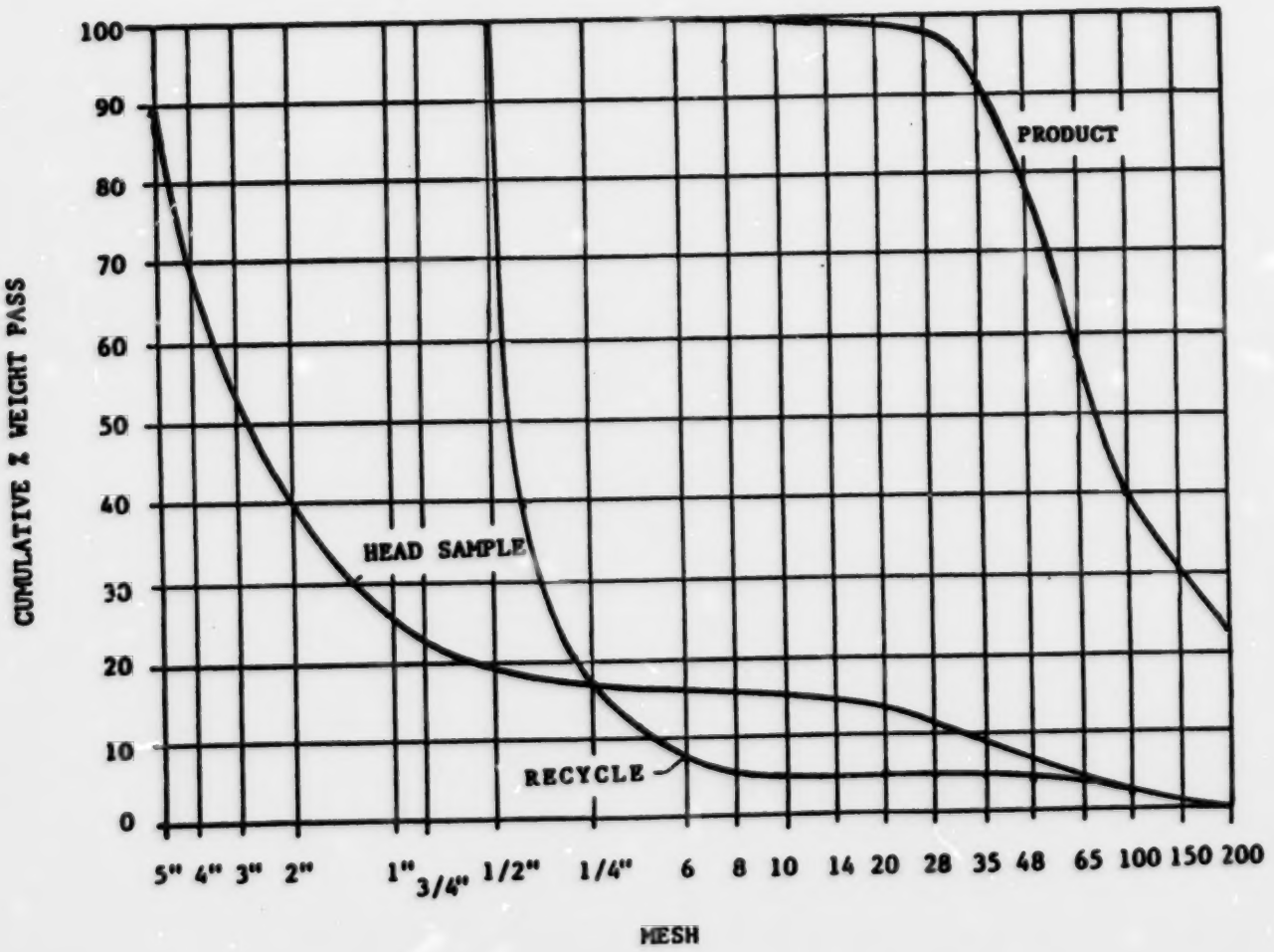
MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	.10	.01	.01	99.99
8	2.4	1.00	.12	.14	99.86
10	1.7	2.90	.36	.49	99.51
14	1.2	2.90	.36	.85	99.15
20	.833	3.30	.41	1.26	98.74
28	.589	6.20	.76	2.02	97.98
35	.420	53.10	6.55	8.57	91.43
48	.295	105.80	13.04	21.61	78.39
65	.208	176.50	21.76	43.37	56.63
100	.147	136.60	16.84	60.21	39.79
150	.105	77.40	9.54	69.75	30.25
200	.074	59.30	7.31	77.06	22.94
-200		186.10	22.94	100.00	0.00
TOTAL		811.20	100.00		

DSS - CANADA CEMENT LAFARGE

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.3

5.3.3-F1

PRODUCT SIZE DISTRIBUTION

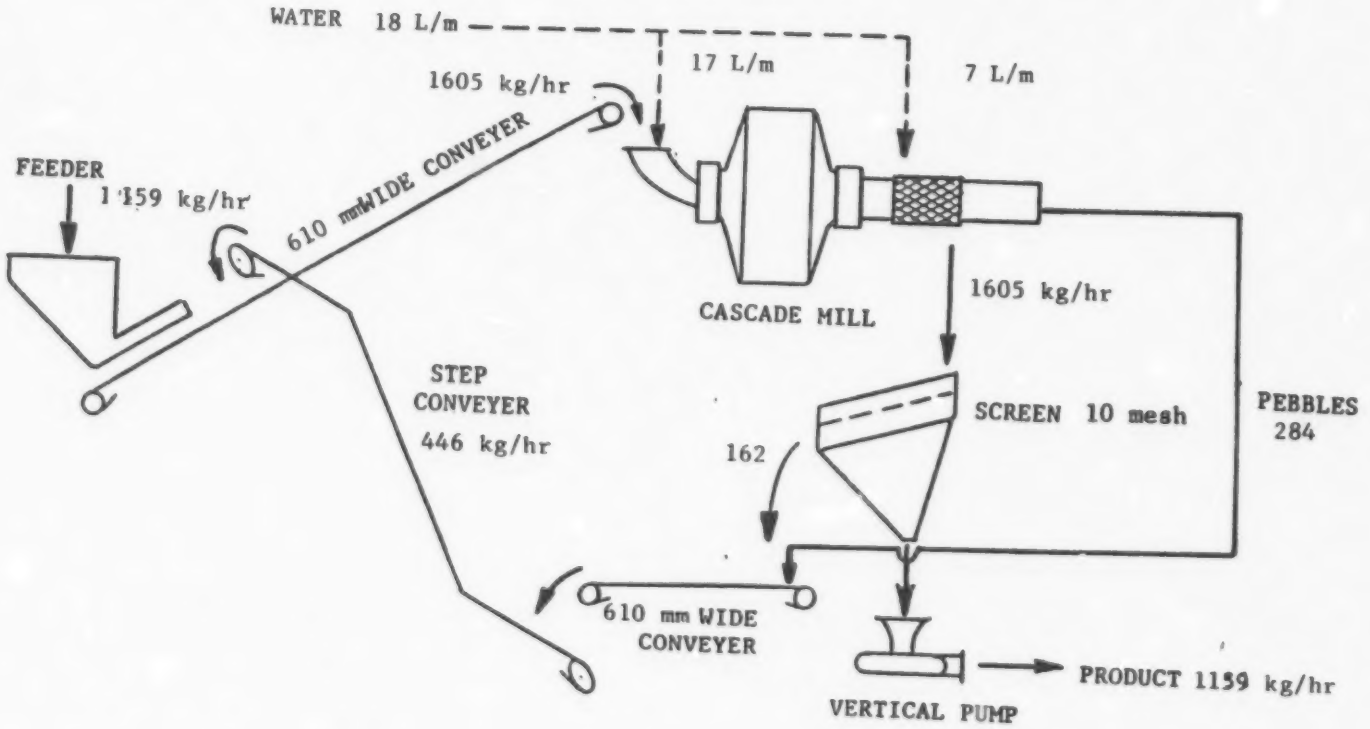


DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

CIRCUIT CONFIGURATION

RUN No. 3



5.3.4 Run No. 4

Purpose: The purpose of this test was to run the mill wet fully autogenous to produce a 100% minus 20 mesh plus 65 mesh material from Steep Rock Quartzite ore. A 6.4mm screen was installed to monitor the effects on the final product.

Description: The test was run for 2 hours, 55 minutes with no technical difficulty. The pebble ports remained open as in Test No. 3, but the 10 mesh screen was replaced with a 6.4mm screen to improve the size distribution of the final product. This screen had little or no effect on the size distribution of the final product. The mill load was dumped after this test.

Classification: 610mm x 1220mm Dillon screen with a 125mm top deck and a 6.4mm bottom deck.

The summary of results is presented in Table 5.3.4-T1.

The size distribution for screen undersize (product) is presented in Table 5.3.4-T2.

The size distribution curves are shown in Figure 5.3.4-F1.

The mass balance flow diagram is presented in Figure 5.3.4-F2.

The mill load size distribution is presented in Table 5.3.4-T3 and Figure 5.3.4-F3.

Table 5.3.4-T1

SUMMARY OF TEST RESULTS

Run No. 4

TYPE OF RUN	Wet Fully Autogenous
% MOISTURE	8%
DRY FEED TO MILL	3396 kg
OPERATING TIME	2 hours, 55 minutes
AVERAGE PRODUCT RATE	1167 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	295 microns
CIRCULATING LOAD	35%
PEBBLES	20.5%
SCREEN O/S	14.5%
% SOLIDS DISCHARGE	65%

NO LOAD POWER DRAW	4.48 kWh
AVERAGE POWER DRAW	11.86 kWh
MILL POWER TRAIN EFFICIENCY	85%
AVERAGE POWER @ MILL SHELL	6.20 kWh
NET MILL POWER CONSUMPTION	5.31 kWh/tonne
WORK INDEX (TONNE)	9.6

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 4
DATE: DEC. 22,1986

FINAL PRODUCT

MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	.70	.11	.11	99.89
8	2.4	2.00	.31	.42	99.58
10	1.7	1.70	.27	.69	99.31
14	1.2	.90	.14	.83	99.17
20	.833	3.00	.47	1.30	98.70
28	.589	4.80	.75	2.05	97.95
35	.420	41.40	6.49	8.54	91.46
48	.295	76.20	11.94	20.48	79.52
65	.208	140.50	22.01	42.49	57.51
100	.147	108.50	17.00	59.49	40.51
150	.105	62.20	9.74	69.23	30.77
200	.074	50.20	7.86	77.10	22.90
-200		146.20	22.90	100.00	0.00
TOTAL		638.30	100.00		

WD1

SIZE DISTRIBUTION

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 4
DATE: DEC. 22,1986

MILL LOAD·

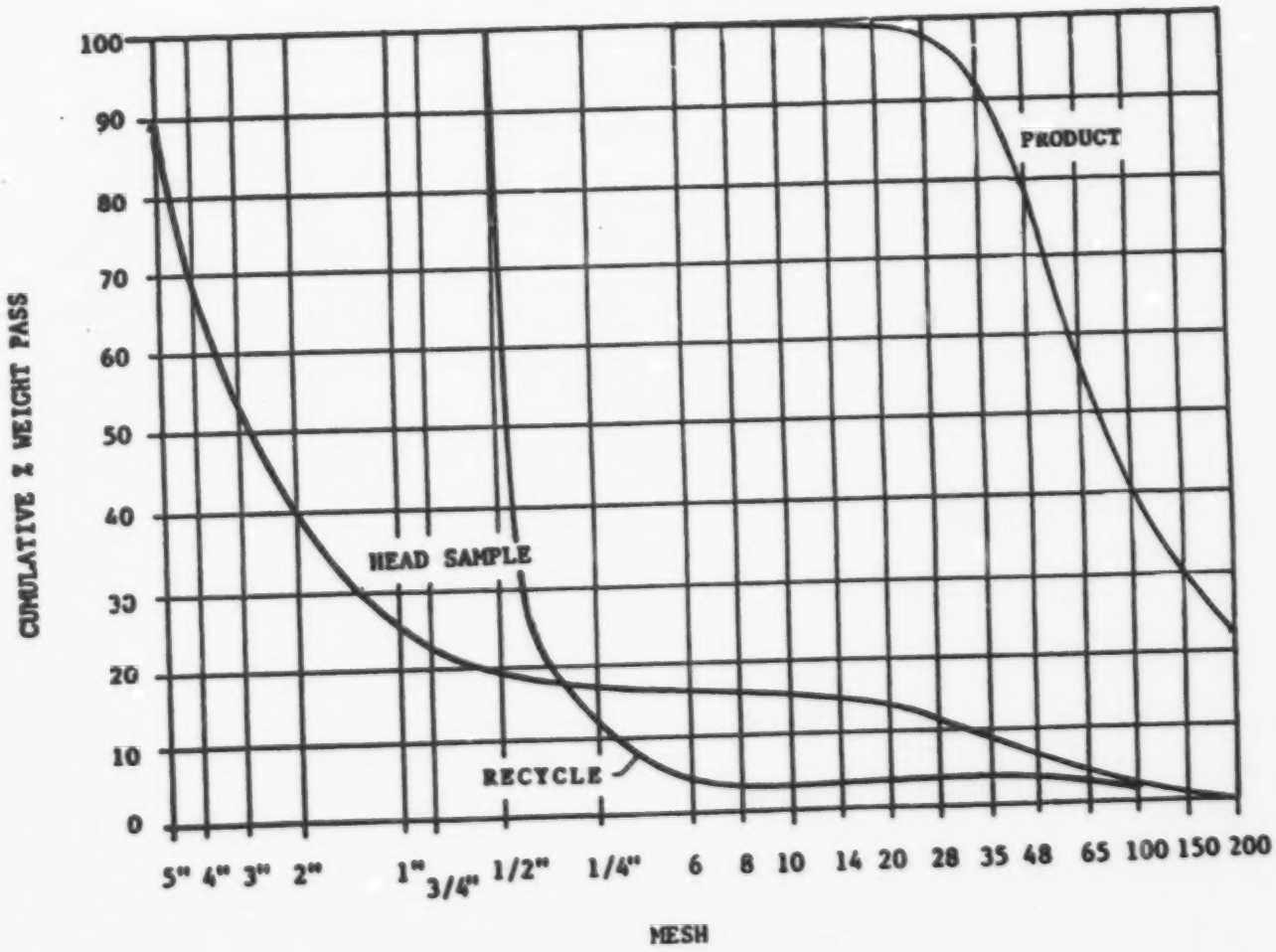
MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	23.00	1.51	1.51	98.49
4"	101	158.00	10.36	11.87	88.13
3"	76	329.00	21.57	33.44	66.56
2"	50.8	457.00	29.97	63.41	36.59
1"	26.7	443.00	29.05	92.46	7.54
3/4"	19.7	0.00	0.00	92.46	7.54
1/2"	12.6	47.00	3.08	95.54	4.46
1/4"	6.4	12.00	.79	96.33	3.67
6	3.3	2.17	.14	96.47	3.53
8	2.4	.42	.03	96.50	3.50
10	1.7	.25	.02	96.51	3.49
14	1.2	.19	.01	96.53	3.47
20	.833	.18	.01	96.54	3.46
28	.589	.30	.02	96.56	3.44
35	.420	3.24	.21	96.77	3.23
48	.295	6.68	.44	97.21	2.79
65	.208	7.60	.50	97.71	2.29
100	.147	12.86	.84	98.55	1.45
150	.105	6.51	.43	98.98	1.02
200	.074	5.44	.36	99.33	.67
-200		10.16	.67	100.00	0.00
TOTAL		1525.00	100.00		

DSS - CANADA CEMENT LAFARGE

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.4

5.3.4-F1

PRODUCT SIZE DISTRIBUTION

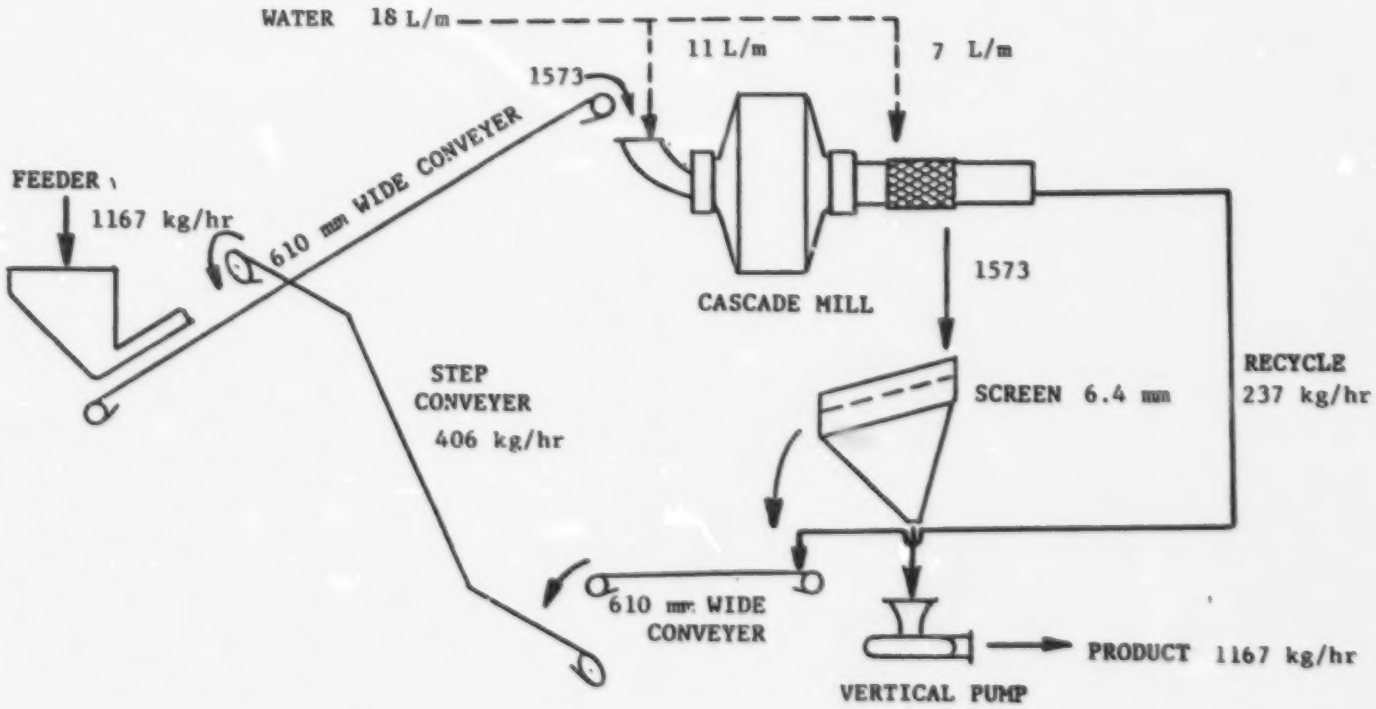


DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

CIRCUIT CONFIGURATION

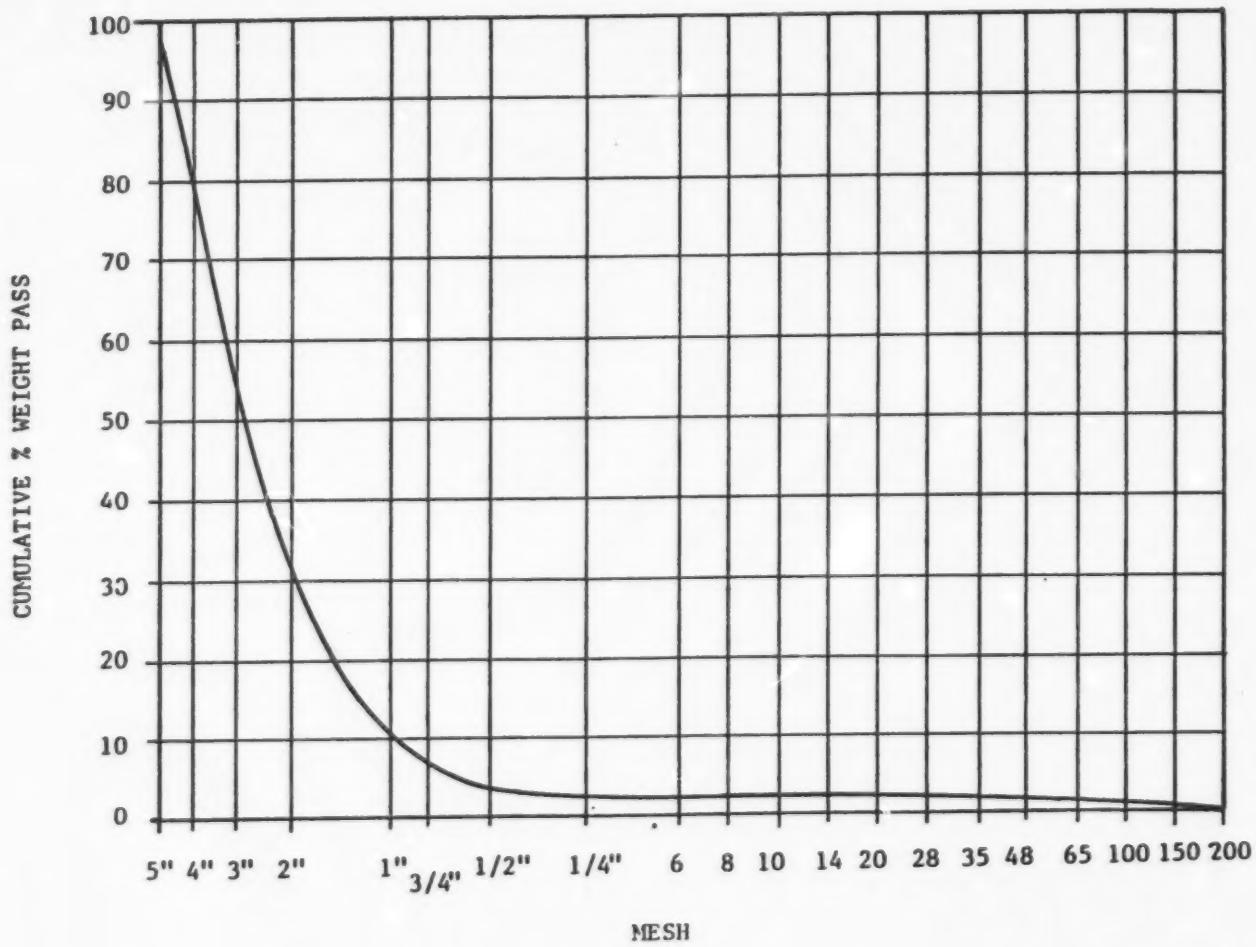
RUN No. 4



DSS - CANADA CEMENT LAFARGE

AUTOGENOUS MILLING OF SILICA ORE
PROJECT 5174 MILL LOAD RUN No.4

SIZE DISTRIBUTION



5.4 Dry Autogenous Milling Results

5.4.1 Run No. 5

Purpose: The purpose of this test was to run the mill fully autogenous, air swept, to produce a 100% minus 20 mesh plus 65 mesh product from Steep Rock Quartzite ore.

Description: The test was started with an empty mill and run fully autogenous and air swept. The circuit was originally run with the circuit configuration as shown in Figure 3.0-F3, with the Gyrotor oversize being returned to the mill. It was apparent that the gyrotor oversize matched the product specifications and that very little material (all of which passed 140 mesh) was recovered from the cyclone. It was decided to collect the gyrotor oversize as final product and run the circuit without recirculating any material.

Classification: Hardinge Gyrotor Air Classifier operating at 205 rpm.
The summary of results is presented in Table 5.4.1-T1.
The size distribution for screen undersize (product) is presented in Table 5.4.1-T2.
The size distribution curves are shown in Figure 5.4.1-F1 and Figures 5.4.1-F2.
The mass balance flow diagram is presented in Figure 5.4.1-F3.

Table 5.4.1-T1

SUMMARY OF TEST RESULTS

Run No. 5

TYPE OF RUN	Dry, Fully Autogenous
% MOISTURE	2%
DRY FEED TO MILL	3191 kg
OPERATING TIME	2 hours, 28 minutes
AVERAGE PRODUCT RATE	1232 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	340 microns
CIRCULATINC LOAD	NA

NO LOAD POWER DRAW	4.56 kWh
AVERAGE POWER DRAW	10.1 kWh
AVERAGE POWER @ MILL SHELL	4.65 kWh
NET MILL POWER CONSUMPTION	3.59 kWh/tonne feed
FAN AVERAGE POWER DRAW	6.08 kWh
FAN AVERAGE POWER NET	5.23 kWh
NET POWER CONSUMPTION	8.02 kWh product
	7.62 kWh/tonne feed
WORK INDEX (TONNE)	7.0

STATIC PRESSURES

MILL	190mm W.G.
GYROTOR	163mm W.G.
CYCLONE	53mm W.G.
DUST COLLECTOR	152mm W.G.
FAN	406mm W.G.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 5
DATE: JAN. 23,1987

FINAL PRODUCT

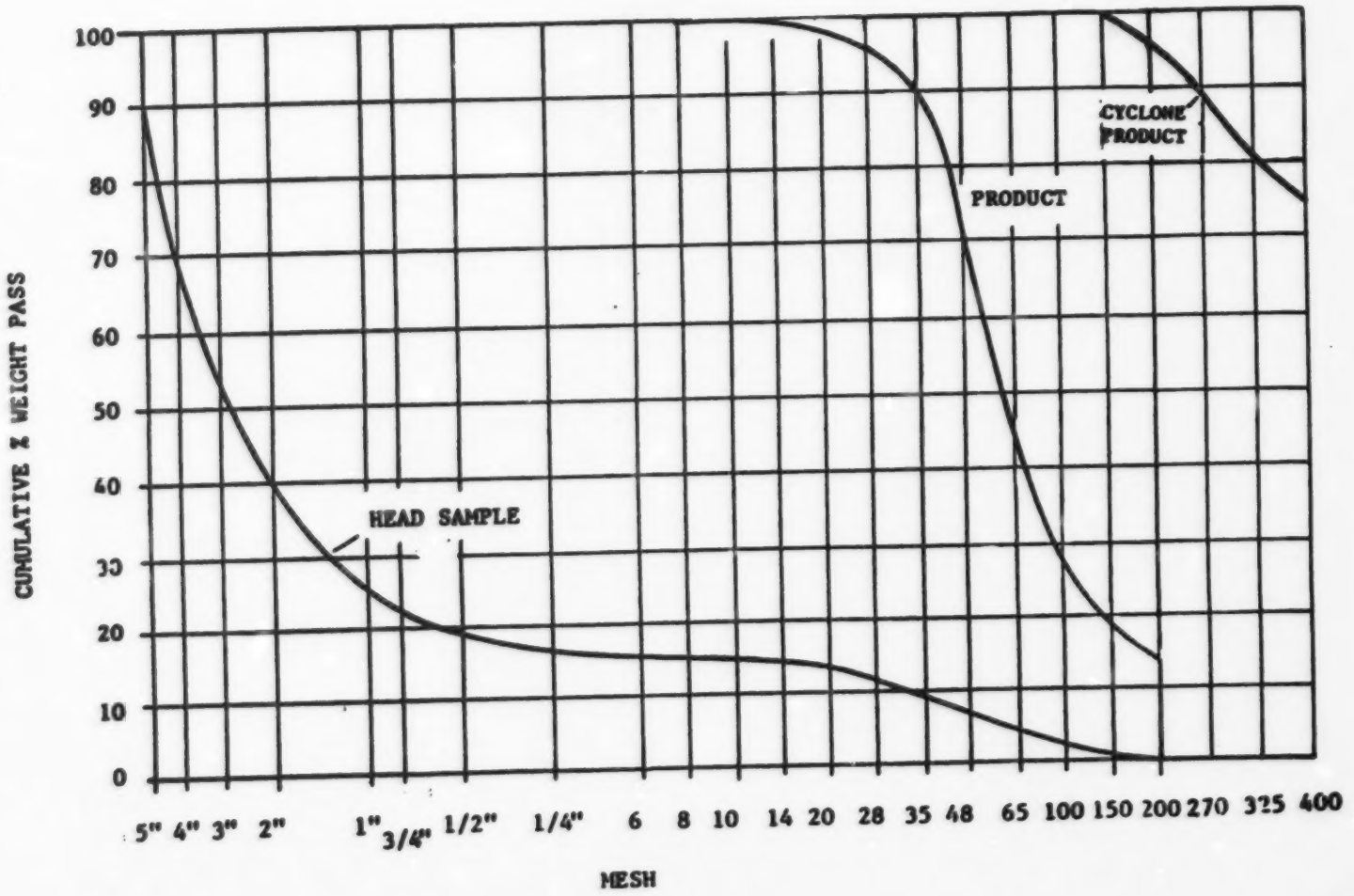
MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	.10	.03	.03	99.97
10	1.7	.20	.05	.08	99.92
14	1.2	.40	.11	.19	99.81
20	.833	.60	.16	.35	99.65
28	.589	2.60	.70	1.05	98.95
35	.420	29.90	8.02	9.06	90.94
48	.295	75.20	20.16	29.22	70.78
65	.208	91.50	24.53	53.75	46.25
100	.147	66.40	17.80	71.55	28.45
150	.105	32.50	8.71	80.27	19.73
200	.074	22.90	6.14	86.41	13.59
-200		50.70	13.59	100.00	0.00
TOTAL		373.00	100.00		

5.4.1-F1

DSS - CANADA CEMENT LAFARGE

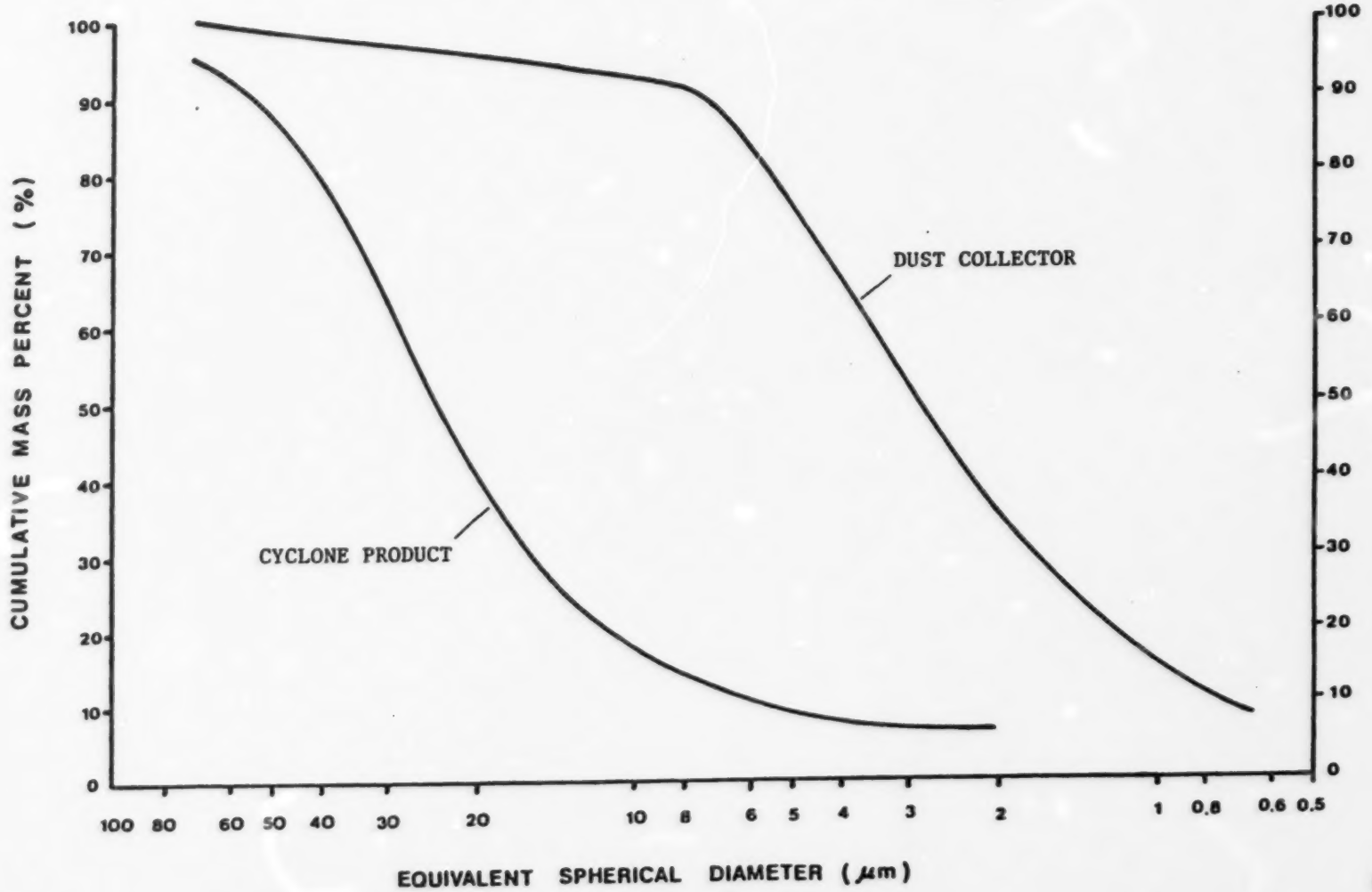
AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.5

PRODUCT SIZE DISTRIBUTION



WD1

D.S.S.- CANADA CEMENT LAFARGE LTD.
AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 RUN No.5

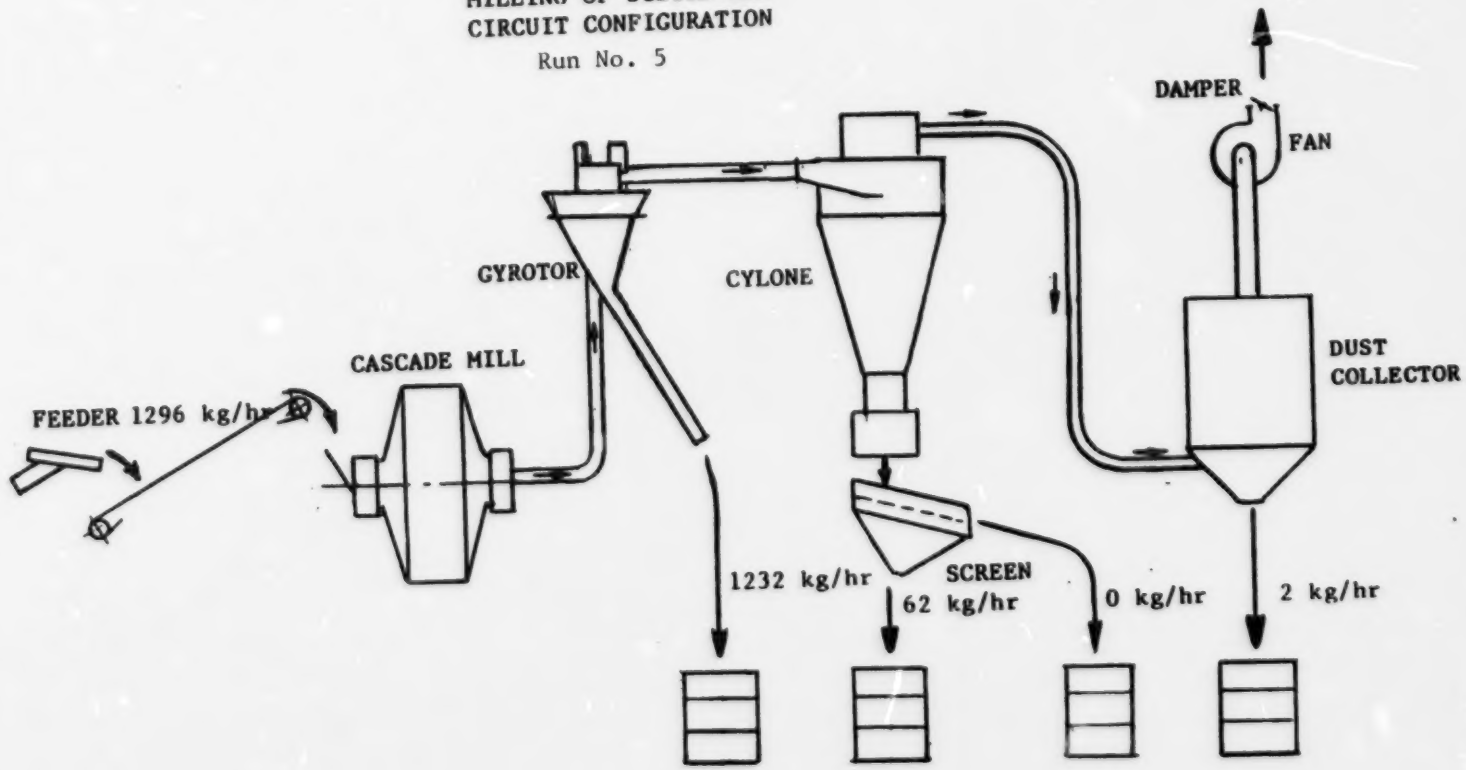


DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS
MILLING OF SILICA ORE
CIRCUIT CONFIGURATION

Run No. 5



5.4.2 Run No. 6

Purpose: The purpose of this test was to operate the mill fully autogenous, air swept, with the fan operating at a higher speed, to monitor its effects on throughput and product quality.

Description: This test was run fully autogenously with an airswept mill. The test ran smoothly for a few hours, until the gyrotor drive belt broke. Since the exact time of the gyrotor breakdown was not noted, the results given are for the reader's information only.

Classification: Hardinge Gyrotor Air Classifier 212 rpm (approximately 3 hours) (0 rpm for approximately 2 hours).
The summary of results is presented in Table 5.4.2-T1.
Size distribution for cyclone product is in Table 5.4.2-T3.
The size distribution for screen undersize (product) is presented in Table 5.4.2-T2.
The size distribution curves are shown in Figure 5.4.2-F1 and 5.4.2-F2.
The mass balance flow diagram is presented in Figure 5.4.2-F3.

Table 5.4.2-T1

SUMMARY OF TEST RESULTS

Run No. 6

TYPE OF RUN	Dry, Fully Autogenous
% MOISTURE	2
DRY FEED TO MILL	6346 kg
OPERATING TIME	5 hours, 15 minutes
AVERAGE PRODUCT RATE	978 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	340 microns
CIRCULATING LOAD	NA

NO LOAD POWER DRAW	4.42 kWh
AVERAGE POWER DRAW	10.34 kWh
AVERAGE POWER @ MILL SHELL	4.97 kWh
NET MILL POWER CONSUMPTION	4.10 kWh/tonne feed
FAN AVERAGE POWER DRAW	6.4 kWh
FAN AVERAGE POWER NET	5.5 kWh
NET POWER CONSUMPTION	10.71 kWh/tonne product
	8.65 kWh/tonne feed
WORK INDEX (TONNE)	7.6

STATIC PRESSURES

MILL	183mm W.G.
GYROTOR	168mm W.G.
CYCLONE	41mm W.G.
DUST COLLECTOR	173mm W.G.
FAN	406mm W.G.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 6
DATE: JAN. 26,1987

FINAL PRODUCT

MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	.05	.01	.01	99.99
10	1.7	.10	.03	.04	99.96
14	1.2	.30	.08	.12	99.88
20	.833	.80	.21	.33	99.67
28	.589	3.00	.79	1.12	98.88
35	.420	29.60	7.77	8.88	91.12
48	.295	66.20	17.38	26.26	73.74
65	.208	79.80	20.94	47.20	52.80
100	.147	87.00	22.83	70.04	29.96
150	.105	34.90	9.16	79.20	20.80
200	.074	24.80	6.51	85.71	14.29
-200		54.45	14.29	100.00	0.00
TOTAL		381.00	100.00		

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 6
DATE: JAN. 26, 1987

CYCLONE PRODUCT

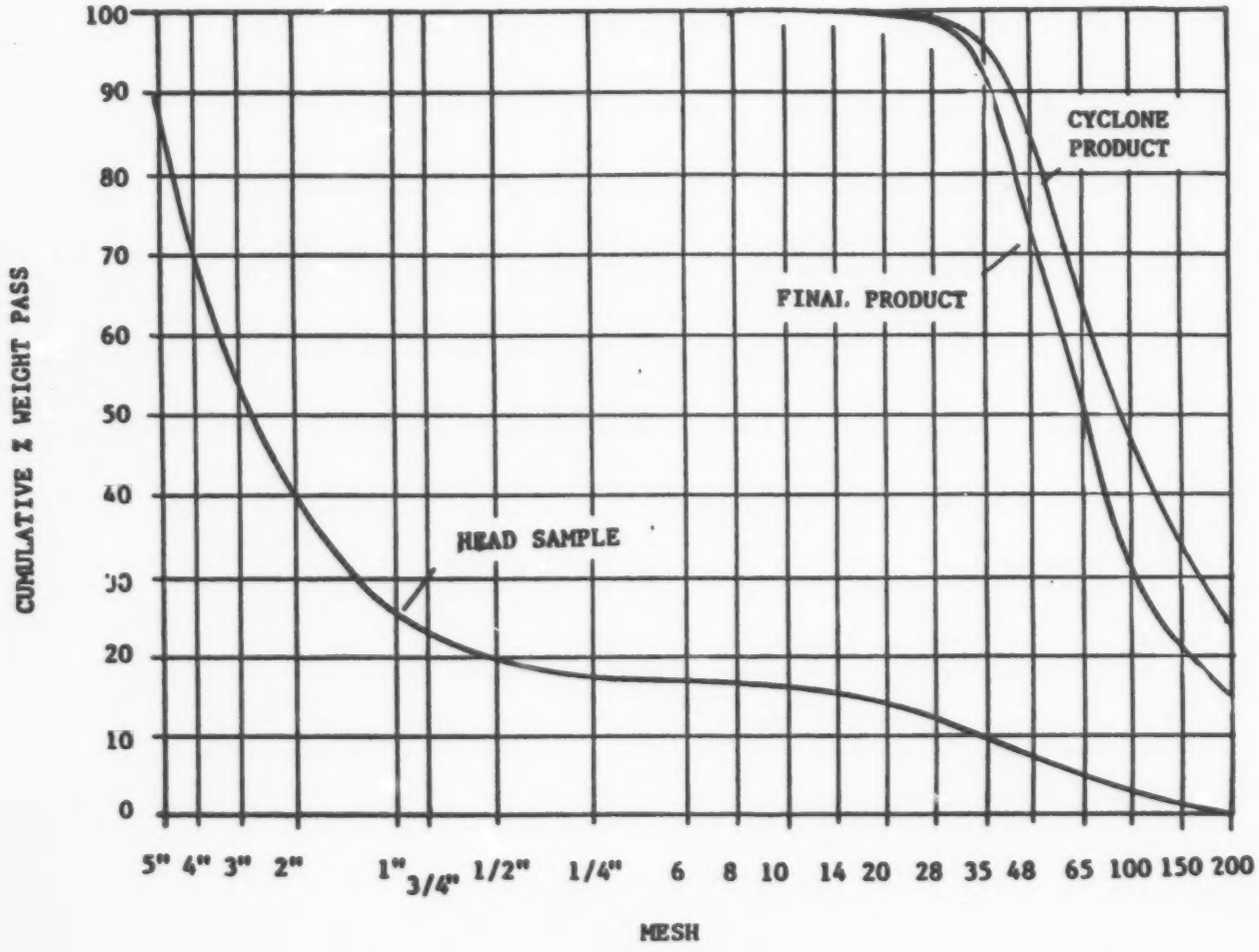
MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	0.00	0.00	0.00	100.00
10	1.7	0.00	0.00	0.00	100.00
14	1.2	0.00	0.00	0.00	100.00
20	.833	.10	.10	.10	99.90
28	.589	1.10	1.10	1.20	98.80
35	.420	2.70	2.70	3.90	96.10
48	.295	11.20	11.20	15.10	84.90
65	.208	20.00	20.00	35.10	64.90
100	.147	18.70	18.70	53.80	46.20
150	.105	11.30	11.30	65.10	34.90
200	.074	10.70	10.70	75.80	24.20
-200		24.20	24.20	100.00	0.00
TOTAL		100.00	100.00		

DSS - CANADA CEMENT LAFARGE

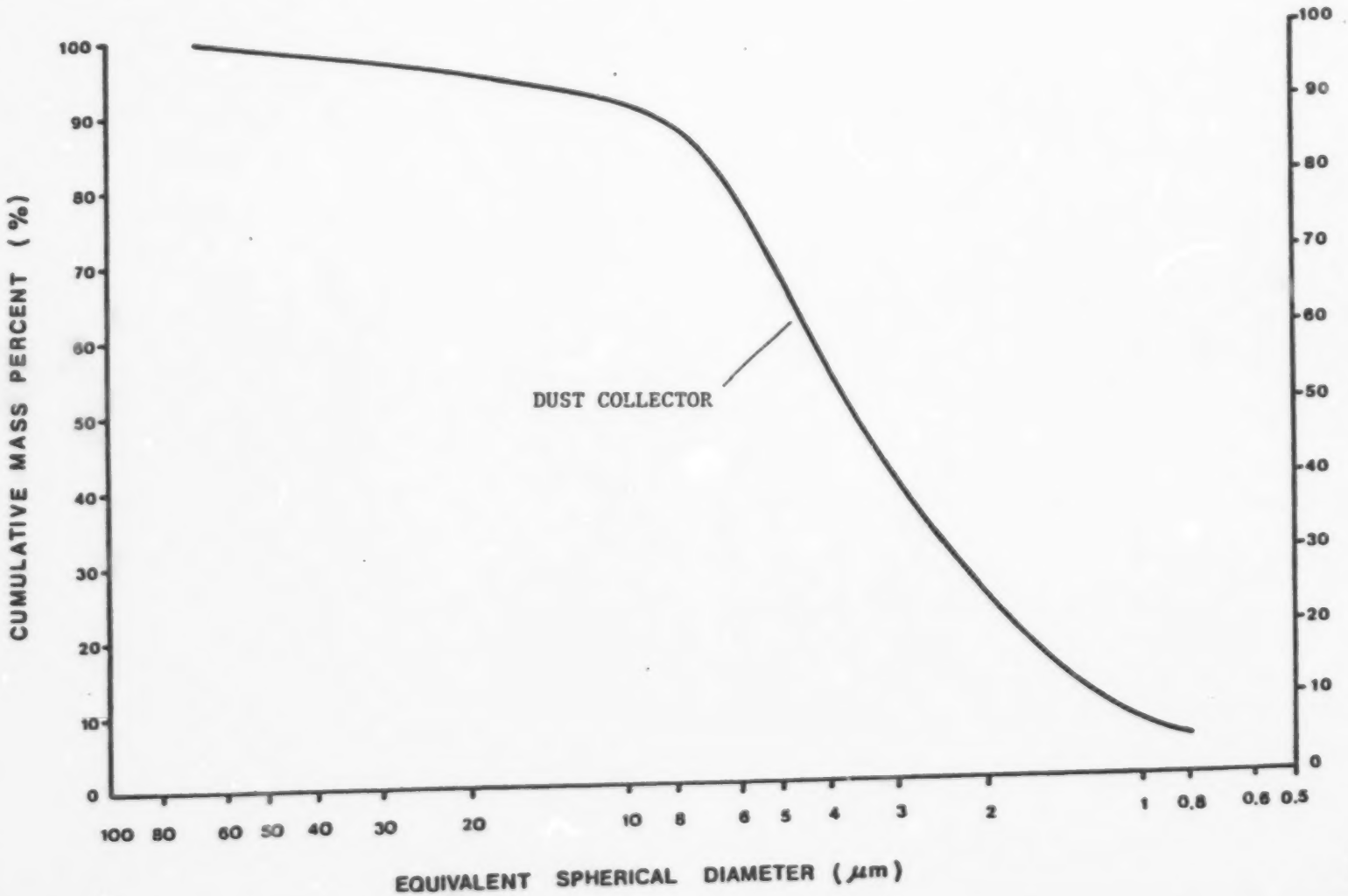
5.4.2-F1

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.6

PRODUCT SIZE DISTRIBUTION



D.S.S.- CANADA CEMENT LAFARGE LTD.
AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 RUN No.6

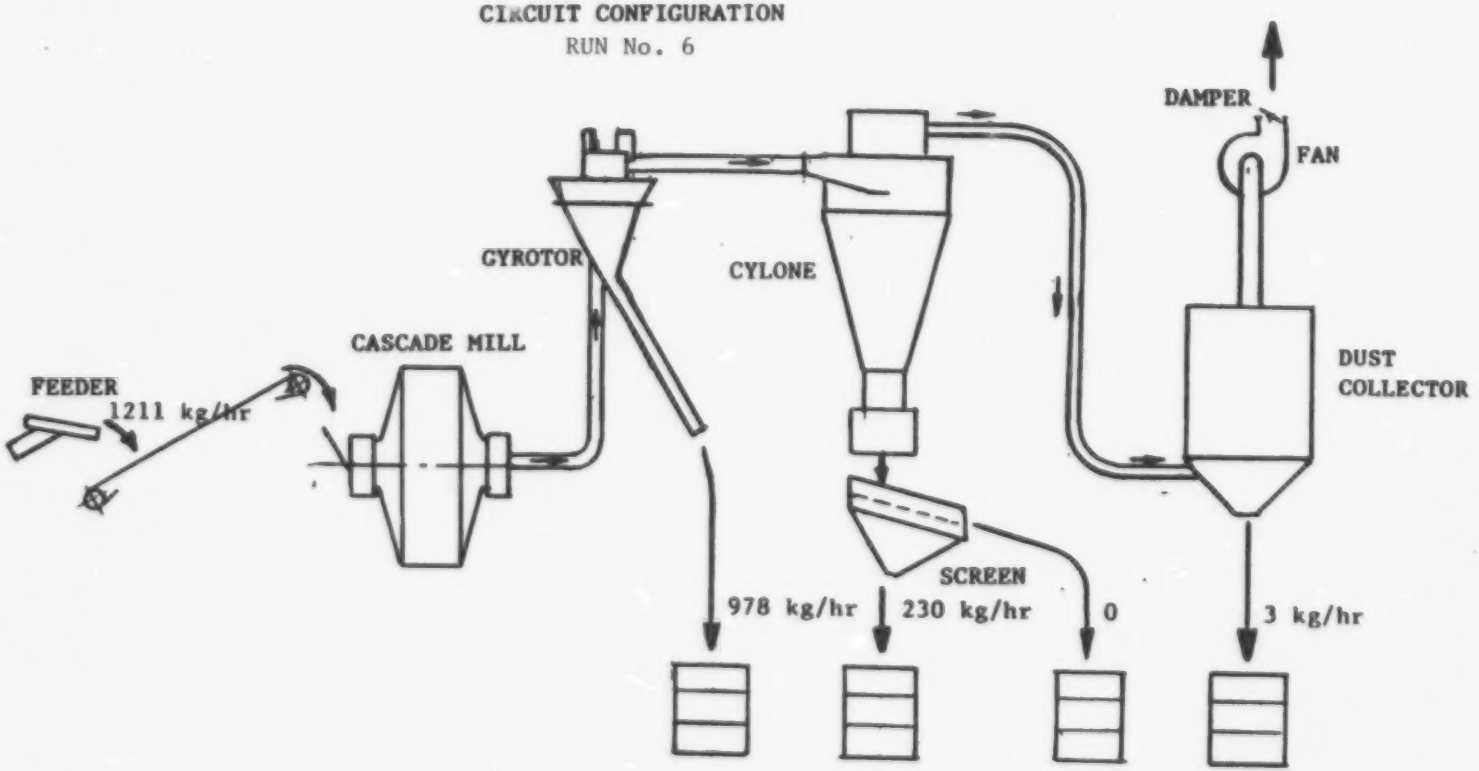


DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS
MILLING OF SILICA ORE
CIRCUIT CONFIGURATION

RUN No. 6



5.4.3 Run No. 7

Purpose: The purpose of this run was to operate the mill fully autogenous, air swept, with the gyrotor operating at a higher speed to remove more fines from the product.

Description: The test was started with a full mill and run for 5 hours and 15 minutes without technical difficulty. The gyrotor speed was increased to 230 rpm in an attempt to clean up the final product but to no effect.

Classification: Hardinge Gyrotor Air Classifier, 230 rpm.

The summary of results is presented in Table 5.4.3-T1.

The size distribution for screen undersize (product) is presented in Table 5.4.3-T2.

The size distribution curves are shown in Figures 5.4.3-F1 and 5.4.3-F2.

The mass balance flow diagram is presented in Figure 5.4.3-F3.

Table 5.4.3-T1

SUMMARY OF TEST RESULTS

Run. No. 7

TYPE OF RUN	Dry, Fully Autogenous
% MOISTURE	3%
DRY FEED TO MILL	6278 kg
OPERATING TIME	5 hours, 21 minutes
AVERAGE PRODUCT RATE	1098 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	340 microns
CIRCULATING LOAD	NA

NO LOAD POWER DRAW	4.48 kWh
AVERAGE POWER DRAW	10.24 kWh
AVERAGE POWER AT MILL SHELL	4.84 kWh
NET MILL POWER CONSUMPTION	4.12 kWh/tonne feed
FAN AVERAGE POWER DRAW	8.56 kWh
FAN AVERAGE POWER NET	7.36 kWh
NET POWER CONSUMPTION	11.11 kWh/tonne product
	10.37 kWh/tonne feed
WORK INDEX (TONNE)	8.1

STATIC PRESSURES

MILL	160mm W.G.
GYROTOR	96mm W.G.
CYCLONE	25mm W.G.
DUST COLLECTOR	-
FAN	508mm W.G.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVITY 6

RUN NO. 7
DATE: JAN. 28,1987

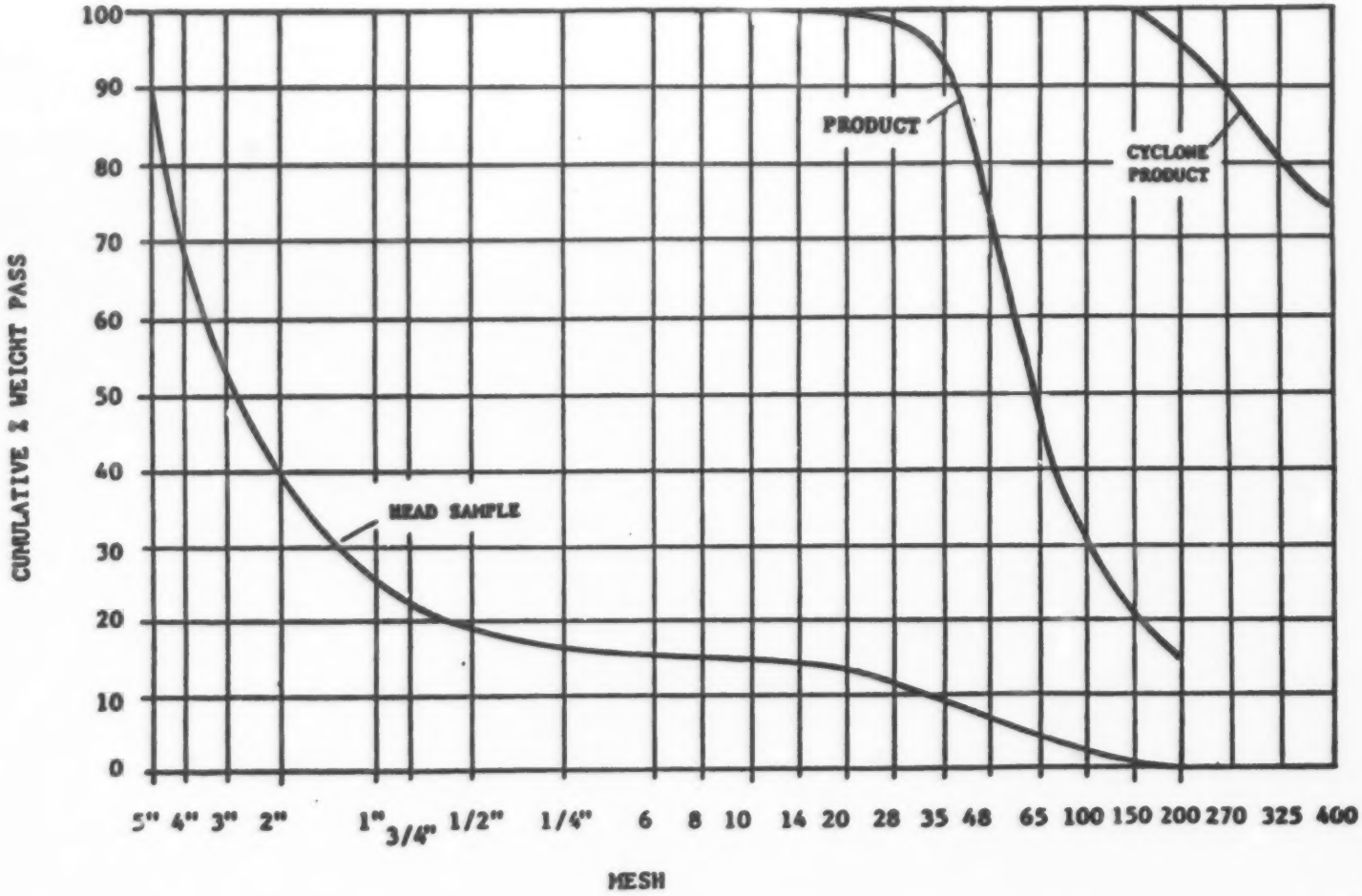
FINAL PRODUCT

MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	.05	.02	.02	99.98
10	1.7	.10	.04	.06	99.94
14	1.2	.20	.08	.14	99.86
20	.833	.60	.24	.38	99.62
28	.589	3.00	1.20	1.58	98.42
35	.420	12.00	4.80	6.38	93.62
48	.295	47.50	19.00	25.38	74.62
65	.208	64.30	25.72	51.10	48.90
100	.147	46.00	18.40	69.50	30.50
150	.105	23.20	9.28	78.78	21.22
200	.074	15.90	6.36	85.14	14.86
-200		37.15	14.86	100.00	0.00
TOTAL		250.00	100.00		

DSS - CANADA CEMENT LAFARGE

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.7

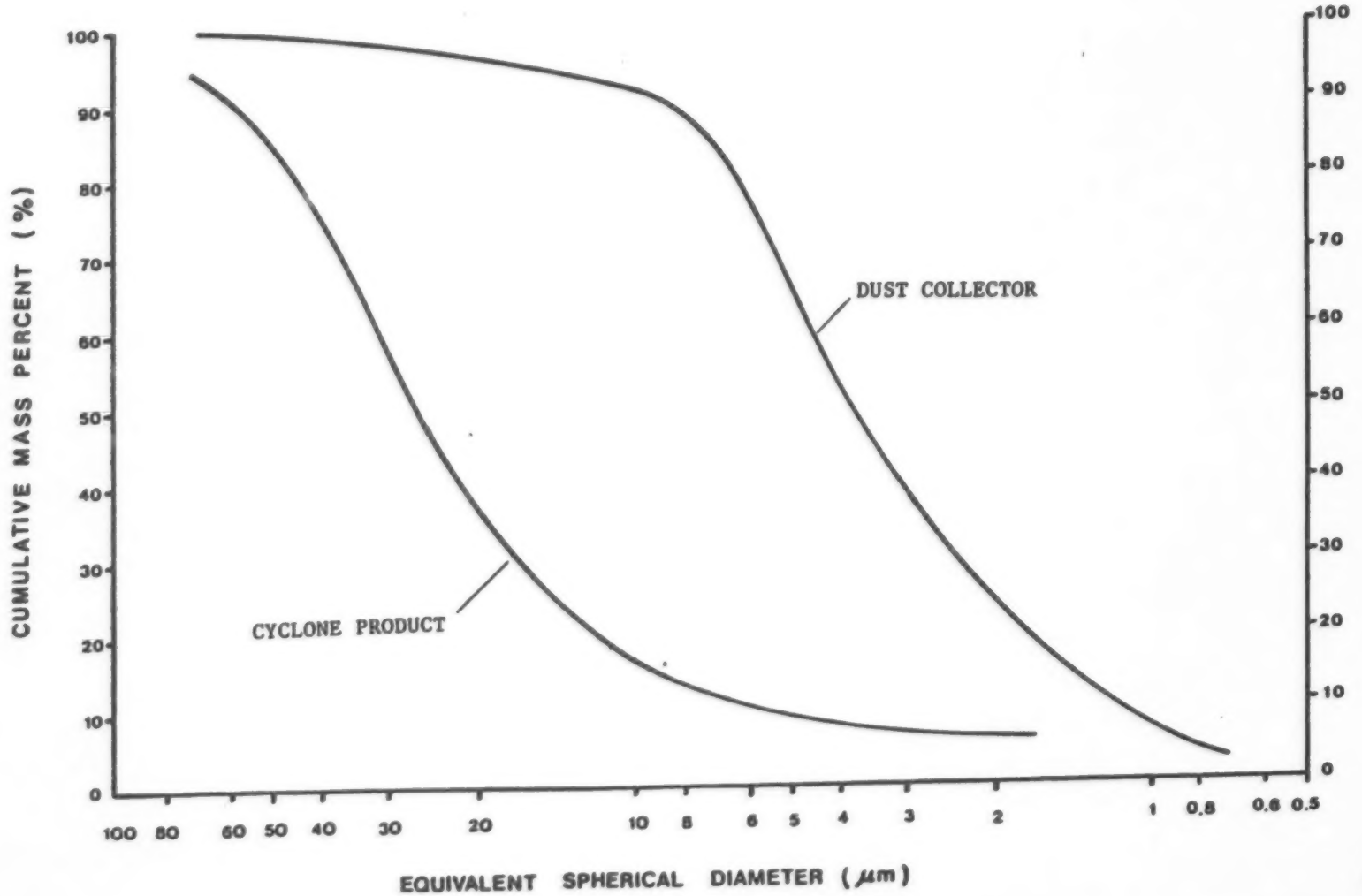
PRODUCT SIZE DISTRIBUTION



WDI

D.S.S.- CANADA CEMENT LAFARGE LTD.
AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 RUN No.7

5.4.3-F2

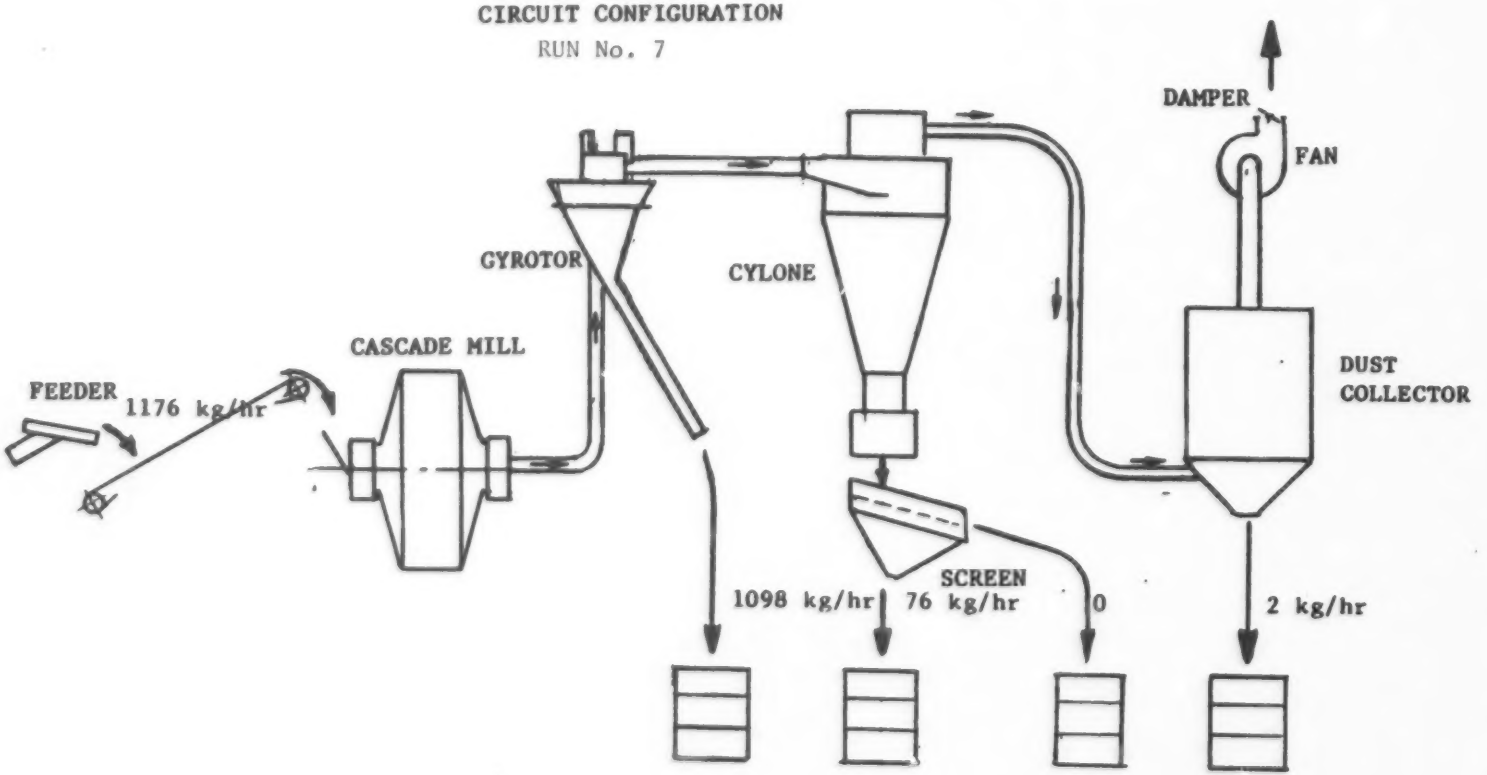


DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS
MILLING OF SILICA ORE
CIRCUIT CONFIGURATION

RUN No. 7



5.4.4 Run No. 8

Purpose: The purpose of this test was to run the mill fully autogenous, air swept to produce a minus 20 mesh plus 65 mesh material from the Steep Rock quartzite ore.

Description: This test was run with a fully loaded mill and an operational gyrotor. The test ran its full length of four hours, 43 minutes with no technical difficulties as the effects of the increased airflow could be monitored. It was noted that apart from altering the pressure drops across the equipment, the increased airflow's affect in throughput and product size was nil.

Classification: Hardinge Gyrotor Air Classifier, 228 rpm.

The summary of results is presented in Table 5.4.4-T1.

The size distribution for screen undersize (product) is presented in Table 5.4.4-T2.

The size distribution curves are shown in Figures 5.4.4-F1 and Figure 5.4.4-F2.

The mass balance flow diagram is presented in Figure 5.4.4-F3.

Table 5.4.4-T1

SUMMARY OF TEST RESULTS

Run. No. 8

TYPE OF RUN	Dry, Fully Autogenous
% MOISTURE	3%
DRY FEED TO MILL	5376 kg
OPERATING TIME	4 hours, 45 minutes
AVERAGE PRODUCT RATE	1068 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	340 microns
CIRCULATING LOAD	NA

NO LOAD POWER DRAW	4.48 kWh
AVERAGE POWER DRAW	10.24 kWh
AVERAGE POWER AT MILL SHELL	4.84 kWh
NET MILL POWER CONSUMPTION	4.26 kWh/tonne feed
FAN AVERAGE POWER DRAW	8.69 kWh
FAN AVERAGE POWER NET	7.47 kWh
NET POWER CONSUMPTION	11.52 kWh/tonne product
	10.85 kWh/tonne feed
WORK INDEX (TONNE)	8.3

STATIC PRESSURES

MILL	155mm W.G.
GYROTOR	94mm W.G.
CYCLONE	43mm W.G.
DUST COLLECTOR	-
FAN	511mm W.G.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 8
DATE: JAN 30, 1987

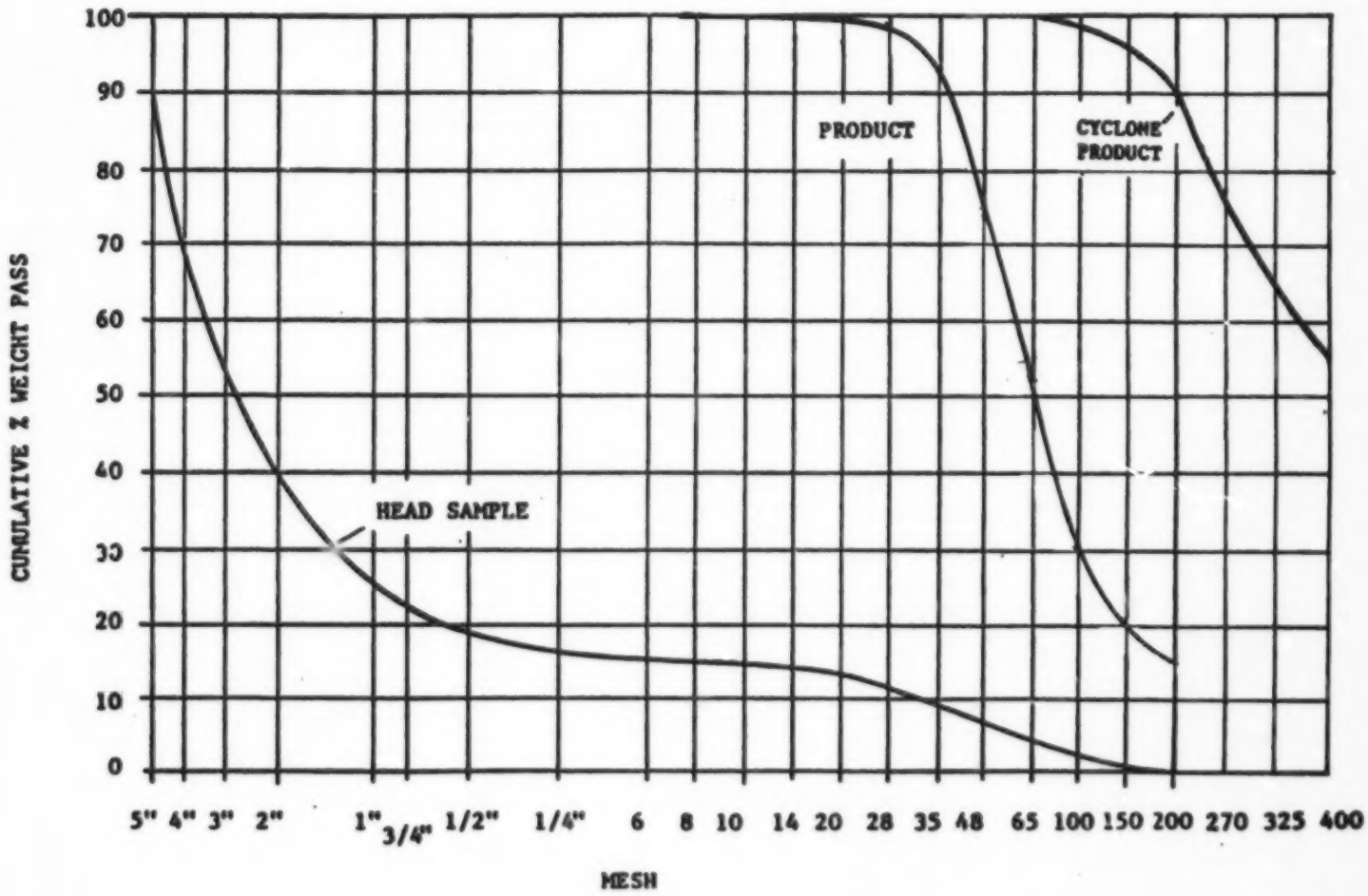
FINAL PRODUCT

MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	.20	.07	.07	99.93
10	1.7	.21	.07	.14	99.86
14	1.2	.53	.18	.32	99.68
20	.833	.97	.33	.64	99.36
28	.589	3.01	1.01	1.66	98.34
35	.420	16.93	5.70	7.36	92.64
48	.295	53.80	18.13	25.49	74.51
65	.208	66.13	22.28	47.77	52.23
100	.147	65.23	21.98	69.75	30.25
150	.105	26.65	8.98	78.73	21.27
200	.074	17.47	5.89	84.61	15.39
-200		45.67	15.39	100.00	0.00
TOTAL		296.80	100.00		

DSS - CANADA CEMENT LAFARGE

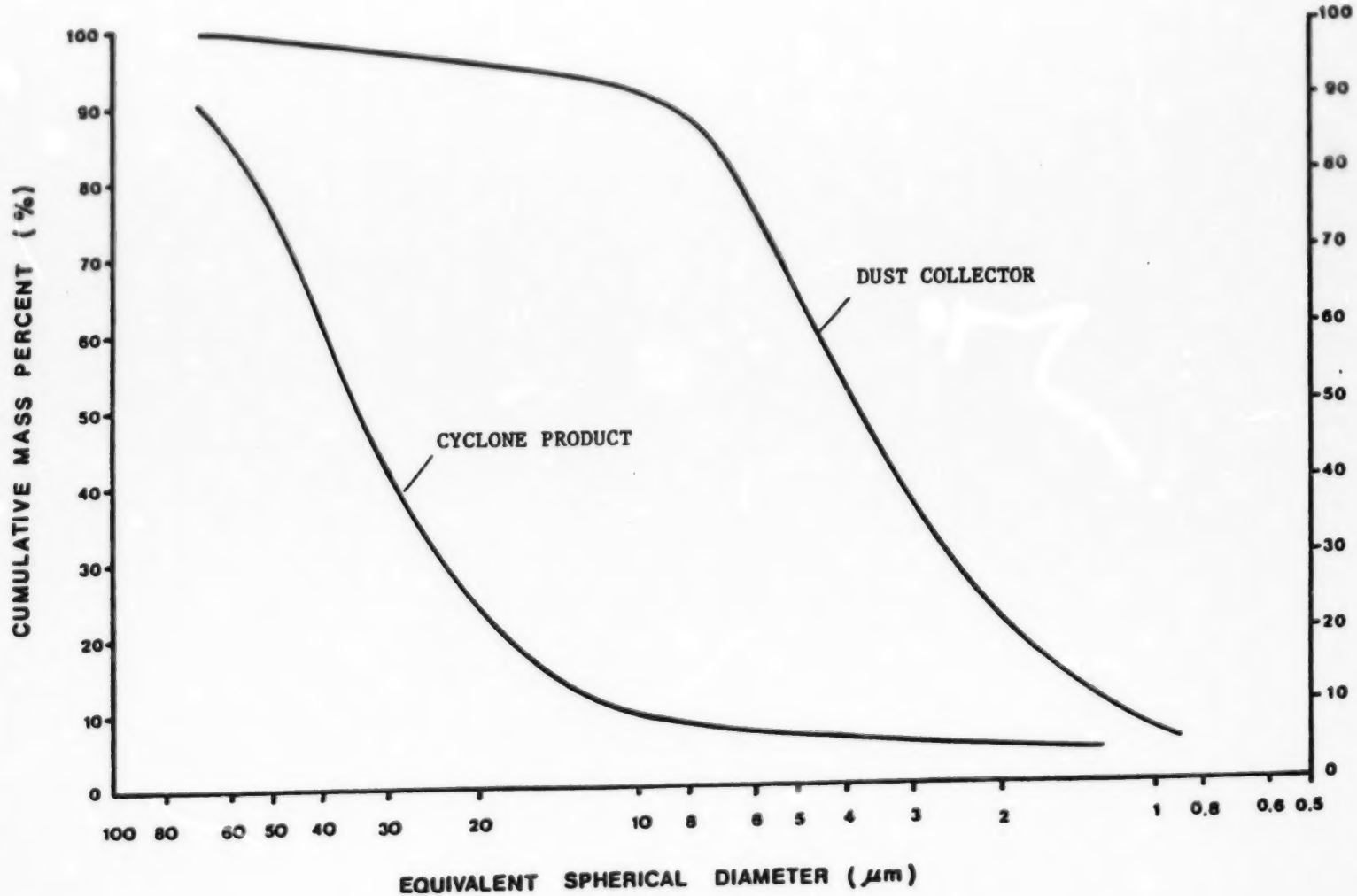
AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.8

PRODUCT SIZE DISTRIBUTION



WD1

D.S.S.- CANADA CEMENT LAFARGE LTD.
AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 RUN No.8

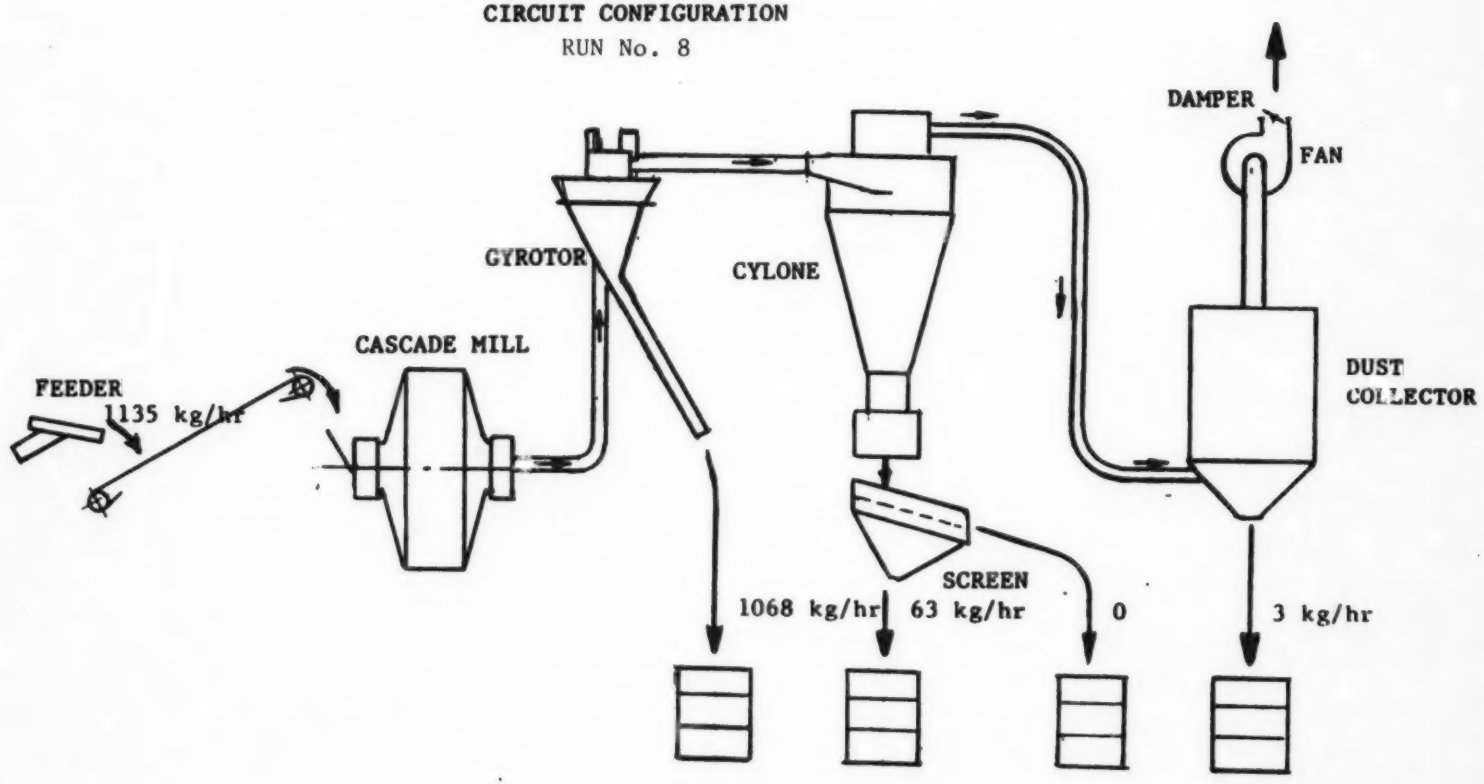


DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS
MILLING OF SILICA ORE
CIRCUIT CONFIGURATION

RUN No. 8



5.4.5 Test No. 9

Purpose: The purpose of this test was to run the mill fully autogenous, air swept to produce a minus 20 mesh plus 65 mesh material from the Steep Rock quartzite ore.

Description: This test was run under the same conditions as Test No. 8, and produced similar results. The mill load was dumped after completion of this test run.

Classification: Hardinge Gyrotor Air Classifier, 228 rpm.

The summary of results is presented in Table 5.4.5-T1.

The size distribution for screen undersize (product) is presented in Table 5.4.5-T2.

The size distribution curves are shown in Figures 5.4.5-F1 and Figure 5.4.5-F2.

The mass balance flow diagram is presented in Figure 5.4.5-F3.

The mill load size distribution is presented in Table 5.4.5-T3 and Figure 5.4.5-F4.

Table 5.4.5-T1

SUMMARY OF TEST RESULTS

Run No. 9

TYPE OF RUN	Dry, Fully Autogenous
% MOISTURE	3%
DRY FEED TO MILL	6553 kg
OPERATING TIME	5 hours, 52 minutes
AVERAGE PRODUCT RATE	1120 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	320 microns
CIRCULATING LOAD	NA

NO LOAD POWER DRAW	4.42 kWh
AVERAGE POWER DRAW	10.39 kWh
AVERAGE POWER AT MILL SHELL	5.01 kWh
NET MILL POWER CONSUMPTION	4.22 kWh/tonne feed
FAN AVERAGE POWER DRAW	8.89 kWh
FAN AVERAGE POWER NET	7.64 kWh
NET POWER CONSUMPTION	11.29 kWh/tonne product
	10.66 kWh/tonne feed
WORK INDEX (TONNE)	8.0

STATIC PRESSURES

MILL	180mm W.G.
GYROTOR	84mm W.G.
CYCLONE	43mm W.G.
DUST COLLECTOR	244mm W.G.
FAN	515mm W.G.

WD1

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 9
DATE: FEB. 3,1987

FINAL PRODUCT

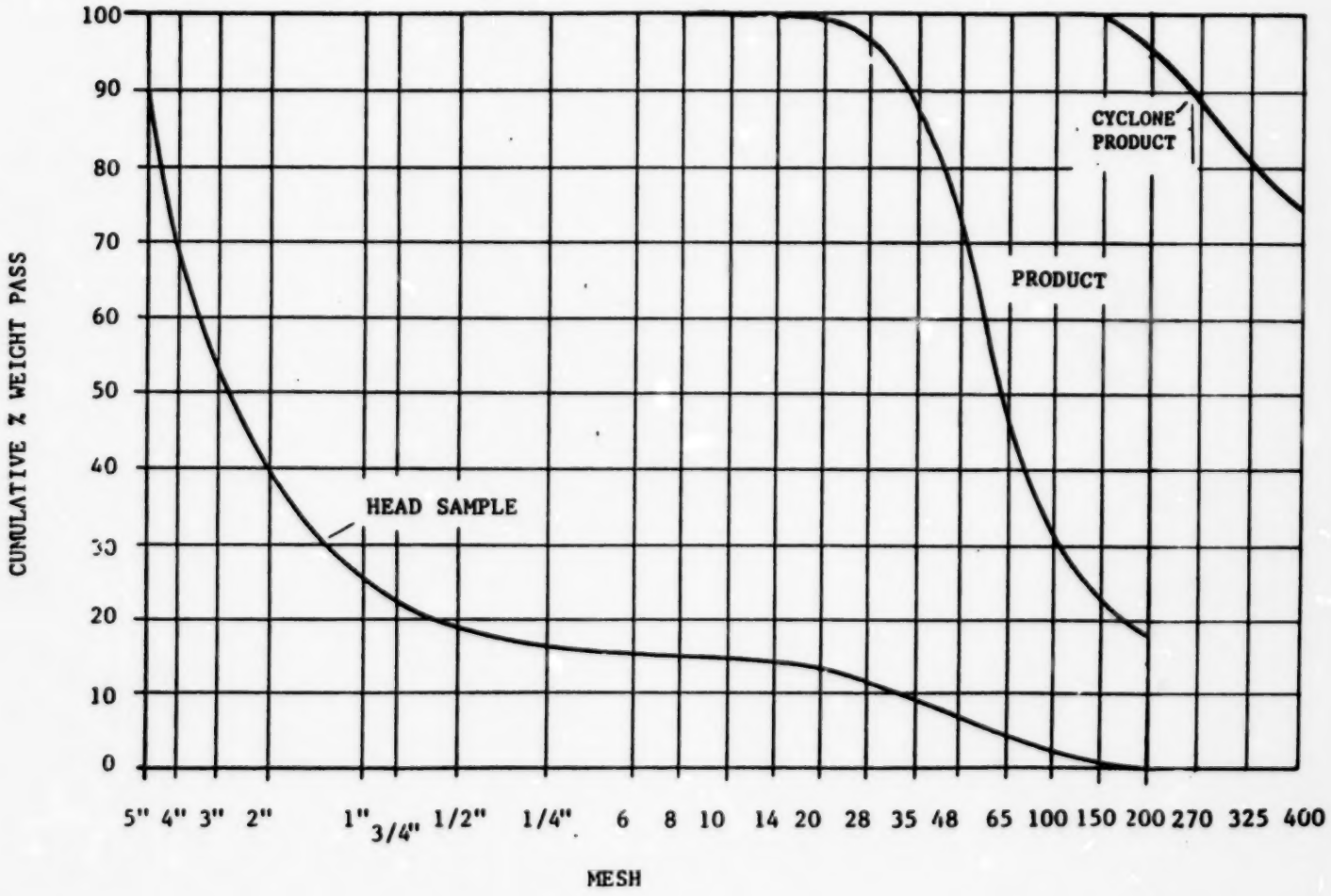
MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	.03	.01	.01	99.99
10	1.7	.11	.04	.05	99.95
14	1.2	.37	.14	.19	99.81
20	.833	.53	.20	.39	99.61
28	.589	2.22	.83	1.23	98.77
35	.420	18.97	7.13	8.36	91.64
48	.295	37.26	14.01	22.36	77.64
65	.208	56.33	21.18	43.54	56.46
100	.147	61.86	23.26	66.80	33.20
150	.105	25.76	9.68	76.48	23.52
200	.074	12.49	4.70	81.18	18.82
-200		50.07	18.82	100.00	0.00
TOTAL		266.00	100.00		

DSS - CANADA CEMENT LAFARGE

5.4.5-F1

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.9

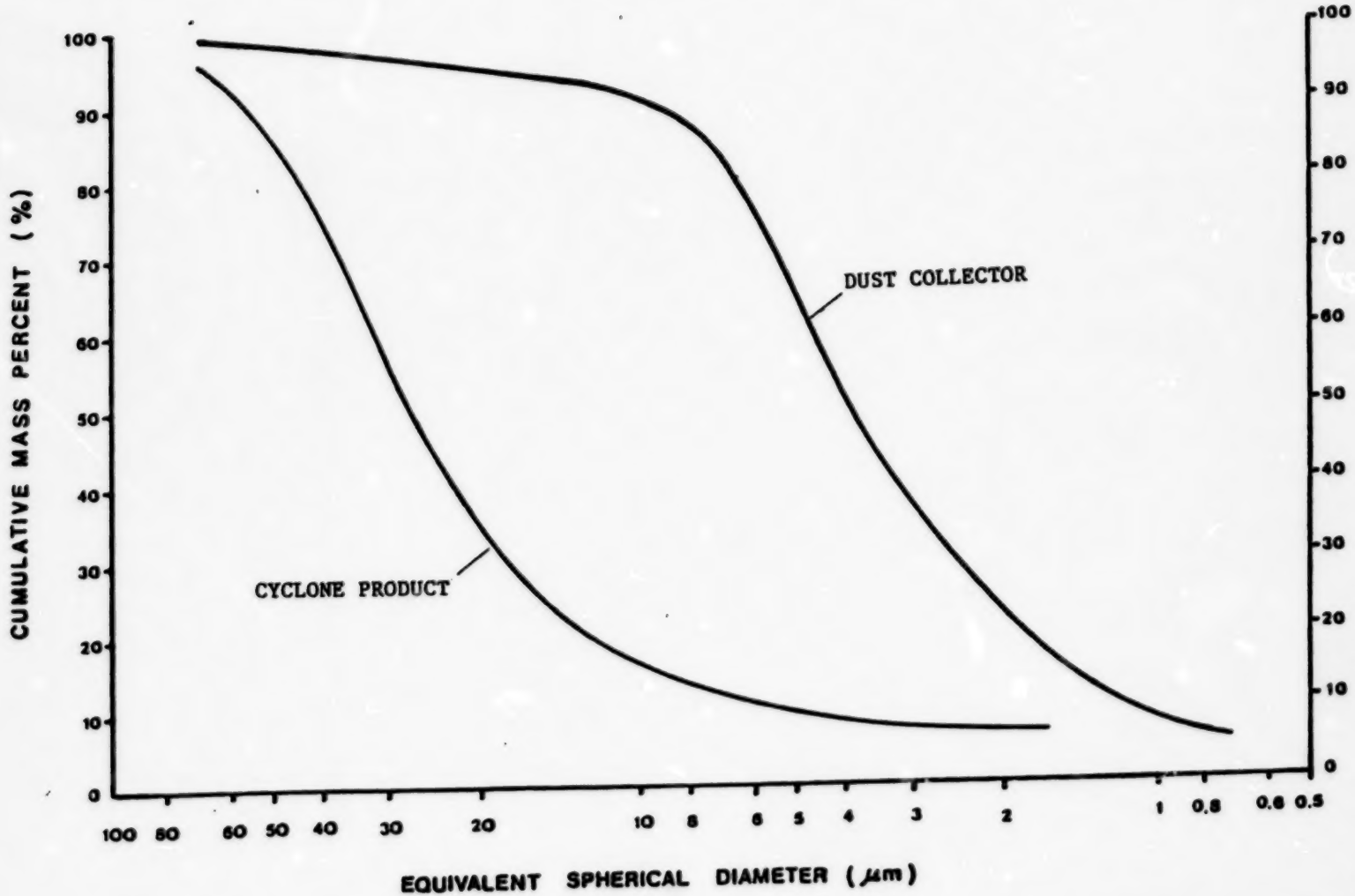
PRODUCT SIZE DISTRIBUTION



WDI

5.4.5-F2

D.S.S.- CANADA CEMENT LAFARGE LTD.
AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 RUN No.9

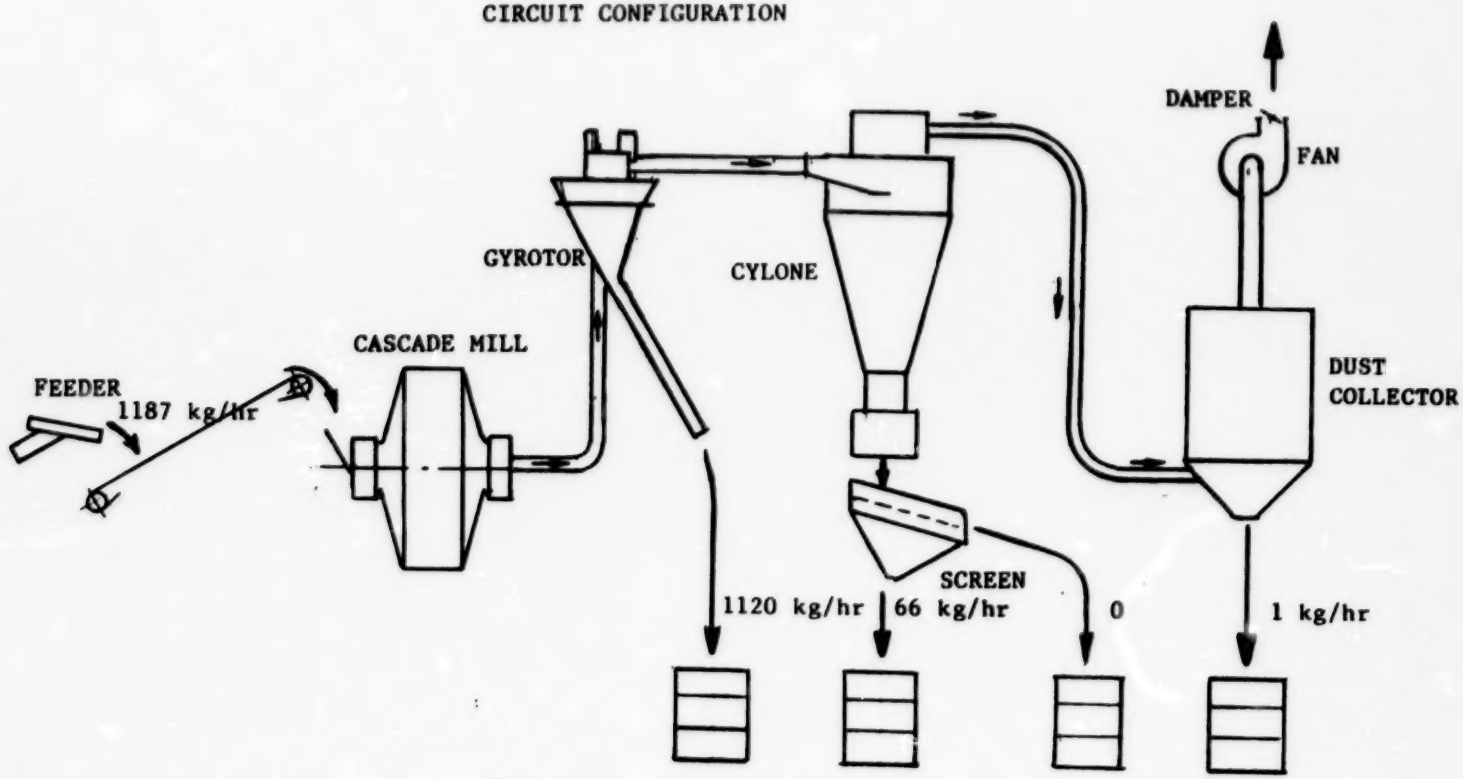


WDI

DSS-CANADA CEMENT LAFARGE

PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS
MILLING OF SILICA ORE
CIRCUIT CONFIGURATION



S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 9
DATE: FEB. 3,1 /87

MILL LOAD RUN NO. 9

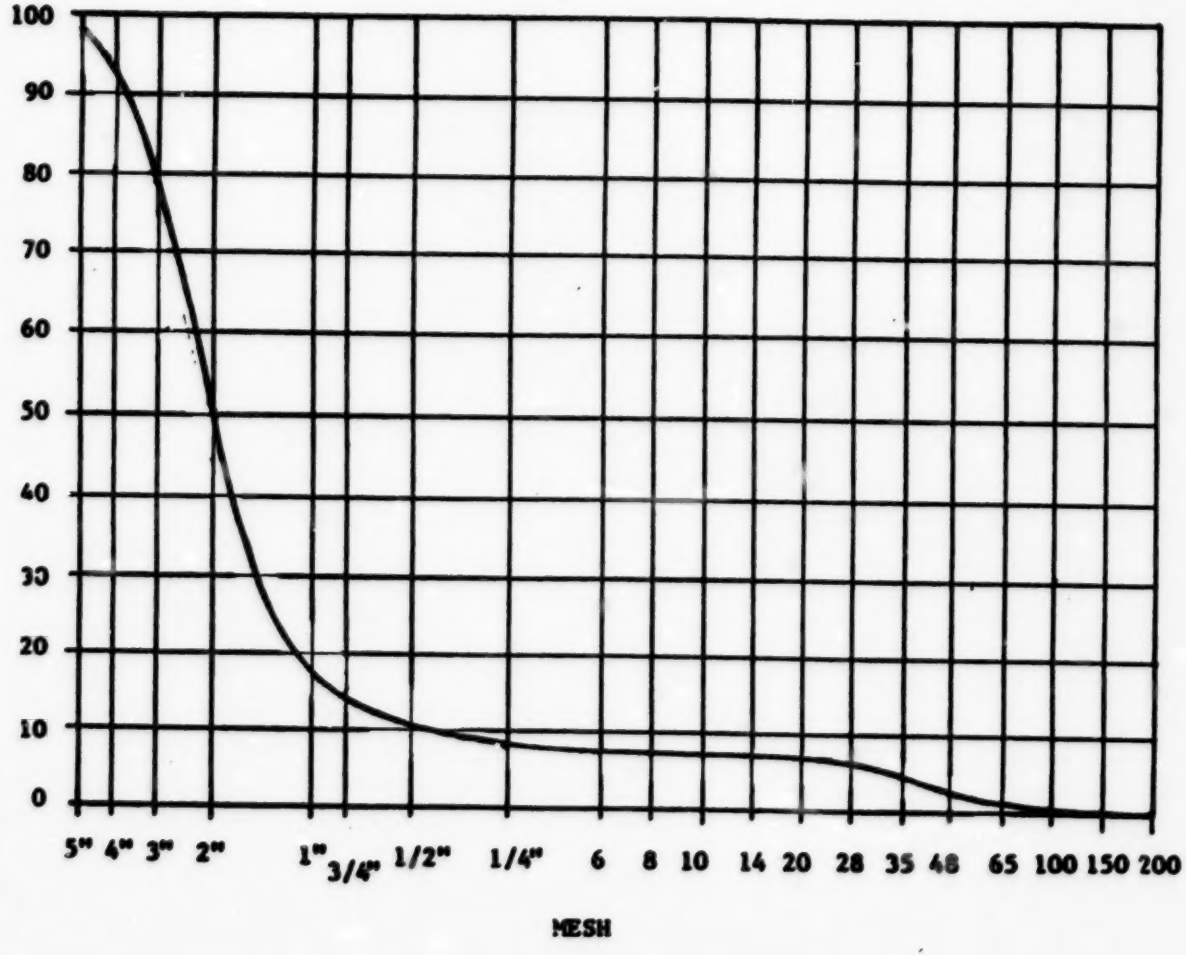
MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	23.00	1.76	1.76	98.24
4"	101	59.00	4.51	6.27	93.73
3"	76	201.00	15.38	21.65	78.35
2"	50.8	356.00	27.24	48.89	51.11
1"	26.7	428.00	32.75	81.64	18.36
3/4"	19.7	0.00	0.00	81.64	18.36
1/2"	12.6	93.00	7.12	88.75	11.25
1/4"	6.4	46.00	3.52	92.27	7.73
6	3.3	8.41	.64	92.92	7.08
8	2.4	1.90	.15	93.06	6.94
10	1.7	1.82	.14	93.20	6.80
14	1.2	1.59	.12	93.32	6.68
20	.833	1.42	.11	93.43	6.57
28	.589	3.40	.26	93.69	6.31
35	.420	16.65	1.27	94.96	5.04
48	.295	35.61	2.72	97.69	2.31
65	.208	16.73	1.28	98.97	1.03
100	.147	5.87	.45	99.42	.58
150	.105	2.14	.16	99.58	.42
200	.074	2.53	.19	99.78	.22
-200		2.93	.22	100.00	0.00
TOTAL		1307.00	100.00		

DSS - CANADA CEMENT LAFARGE

5.4.5-F4

AUTOGENOUS MILLING OF SILICA ORE

PROJECT 5174 MILL LOAD RUN No.9



WD1

5.4.6 Test No. 10

Purpose: The purpose of this test was to run the mill fully autogenous, air swept to produce a minus 20 mesh plus 65 mesh product from Steep Rock quartzite. The Gyrotor oversize was screened at 14 mesh to recycle oversize material.

Description: This test was started with an empty mill and run for 2 hours, 37 minutes until shutdown. A 14 mesh screen was used to remove oversize material from the Gyrotor oversize. This material was weighed and then returned to the circuit for regrind. No technical difficulties were encountered as the moisture content of the feed material averaged 1%.

Classification: Primary: Hardinge Gyrotor, Air Classifier, 228 rpm

Secondary: 610mm x 1220mm Dillon Vibrating Screen with a 14 mesh single deck screen.

The summary of results is presented in Table 5.4.6-T1.

The size distribution for screen undersize (product) is presented in Table 5.4.6-T2.

The size distribution for screen oversize is presented in Table 5.4.6-T3.

The size distribution curves are shown in Figure 5.4.6-F1 and Figure 5.4.6-F2.

The mass balance flow diagram is presented in Figure 5.4.6-F3.

Table 5.4.6-T1

SUMMARY OF TEST RESULTS

Run No. 10

TYPE OF RUN	Dry, Fully Autogenous
% MOISTURE	1%
DRY FEED TO MILL	3374 kg
OPERATING TIME	2 hours, 37 minutes
AVERAGE PRODUCT RATE	1187 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	370 microns
CIRCULATING LOAD	1.05%

NO LOAD POWER DRAW	4.56 kWh
AVERAGE POWER DRAW	9.68 kWh
AVERAGE POWER AT MILL SHELL	4.30 kWh
NET MILL POWER CONSUMPTION	3.33 kWh/tonne feed
FAN AVERAGE POWER DRAW	9.49 kWh
FAN AVERAGE POWER NET	8.16 kWh
NET POWER CONSUMPTION	10.49 kWh/tonne product
	9.64 kWh/tonne feed
WORK INDEX (TONNE)	6.8

STATIC PRESSURES

MILL	191mm W.G.
GYROTOR	41mm W.G.
CYCLONE	46mm W.G.
DUST COLLECTOR	193mm W.G.
FAN	520mm W.G.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 10
DATE: FEB 13,1987

PRIMARY SCREEN UNDERSIZE

MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	0.00	0.00	0.00	100.00
10	1.7	0.00	0.00	0.00	100.00
14	1.2	0.00	0.00	0.00	100.00
20	.833	3.10	.30	.30	99.70
28	.589	12.20	1.20	1.50	98.50
35	.420	16.00	1.57	3.07	96.93
48	.295	541.20	53.14	56.21	43.79
65	.208	139.90	13.74	69.95	30.05
100	.147	151.50	14.87	84.82	15.18
150	.105	63.50	6.23	91.06	8.94
200	.074	50.70	4.98	96.03	3.97
-200		40.40	3.97	100.00	0.00
TOTAL		1018.50	100.00		

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 10
DATE: FEB 13,1987

PRIMARY SCREEN OVERSIZE

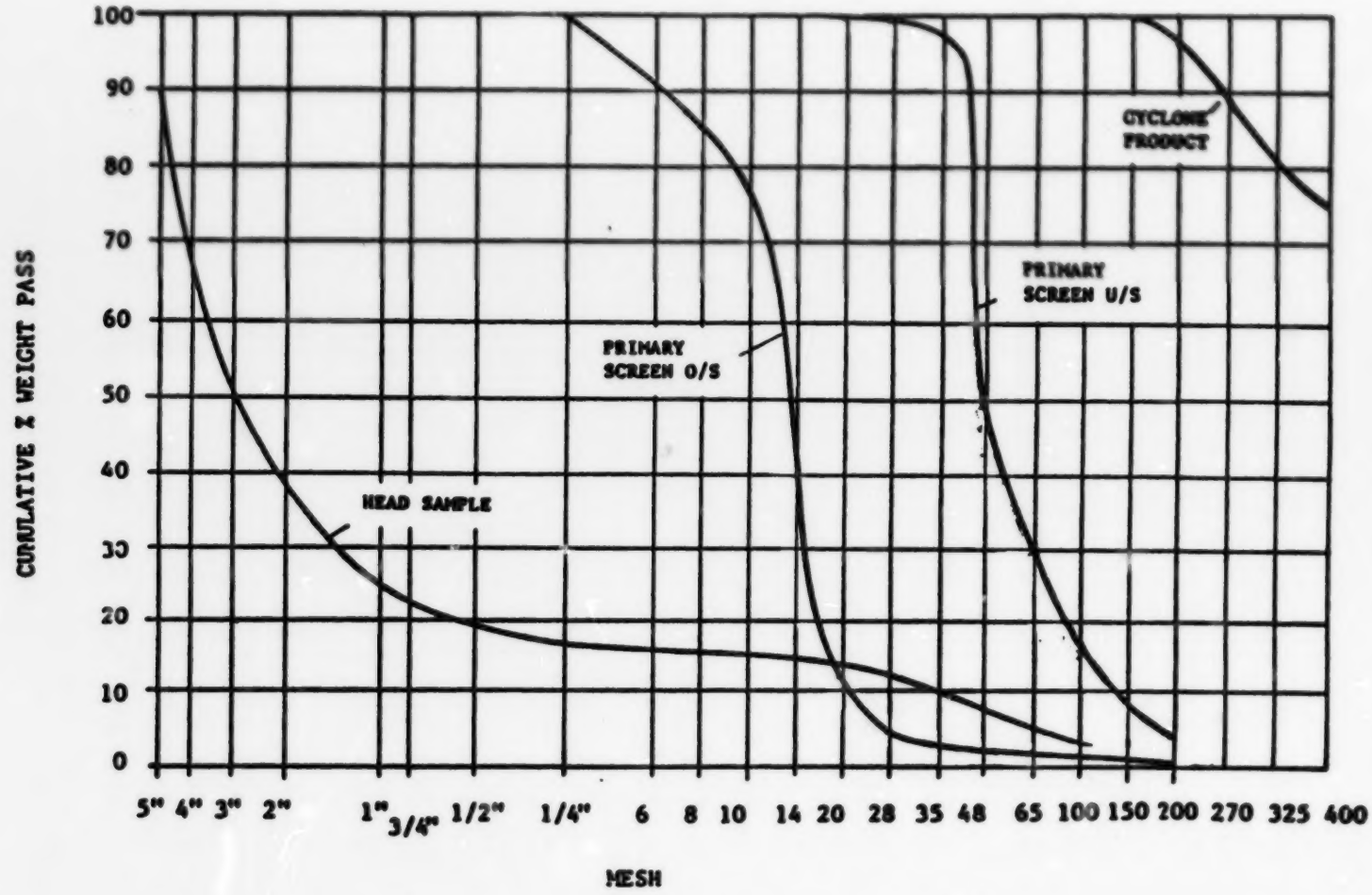
MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	58.90	9.33	9.33	90.67
8	2.4	34.00	5.39	14.72	85.28
10	1.7	48.60	7.70	22.42	77.58
14	1.2	196.40	31.13	53.55	46.45
20	.833	224.60	35.59	89.14	10.86
28	.589	42.20	6.69	95.83	4.17
35	.420	4.80	.76	96.59	3.41
48	.295	6.50	1.03	97.62	2.38
65	.208	2.40	.38	98.00	2.00
100	.147	2.00	.32	98.32	1.68
150	.105	1.20	.19	98.51	1.49
200	.074	1.30	.21	98.72	1.28
-200		8.10	1.28	100.00	0.00
TOTAL		631.00	100.00		

DSS - CANADA CEMENT LAFARGE

5.4.6-F1

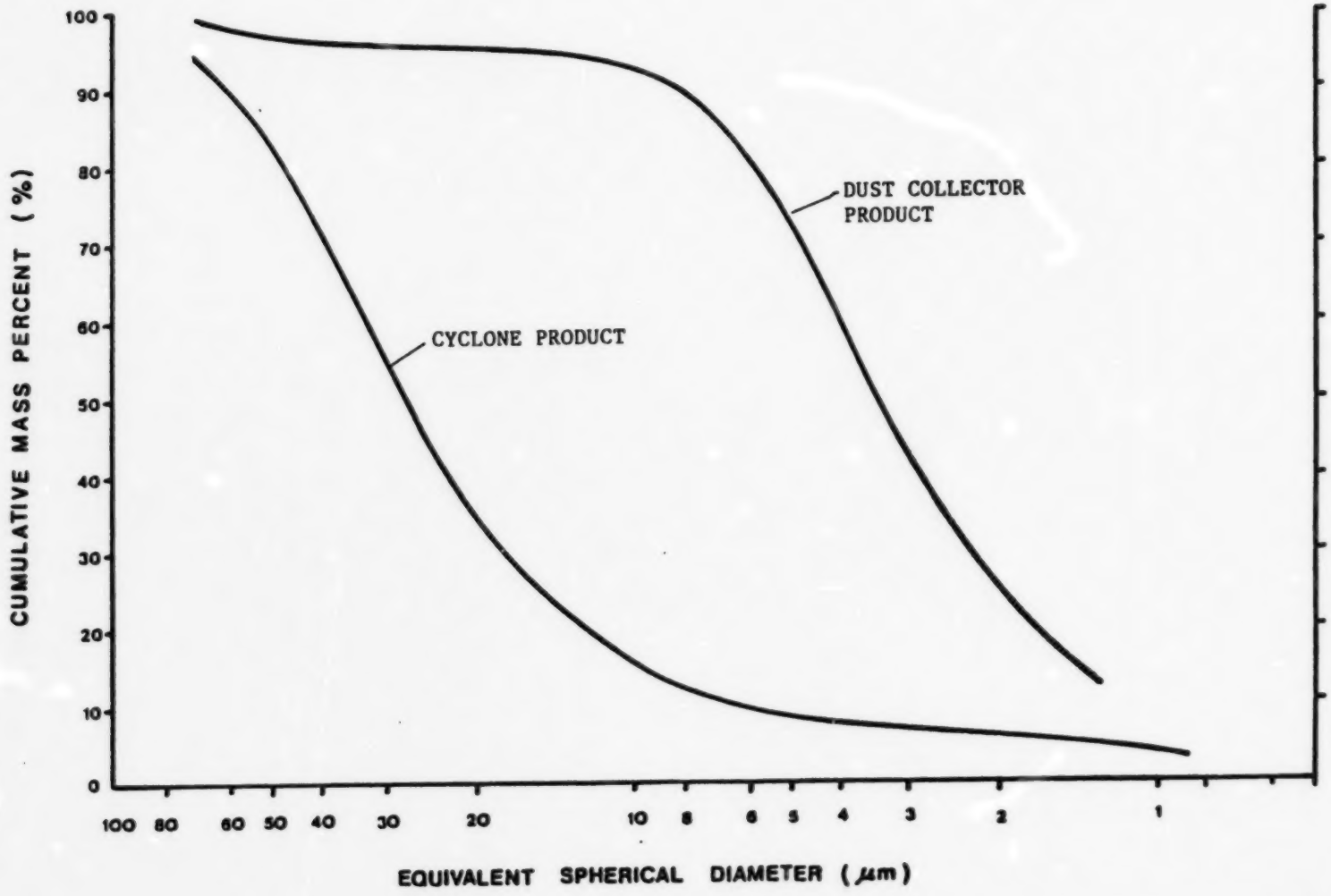
AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.10

PRODUCT SIZE DISTRIBUTION



WD1

D.S.S.- CANADA CEMENT LAFARGE LTD.
AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 . RUN No.10



WDI

DSS-CANADA CEMENT LAFARGE

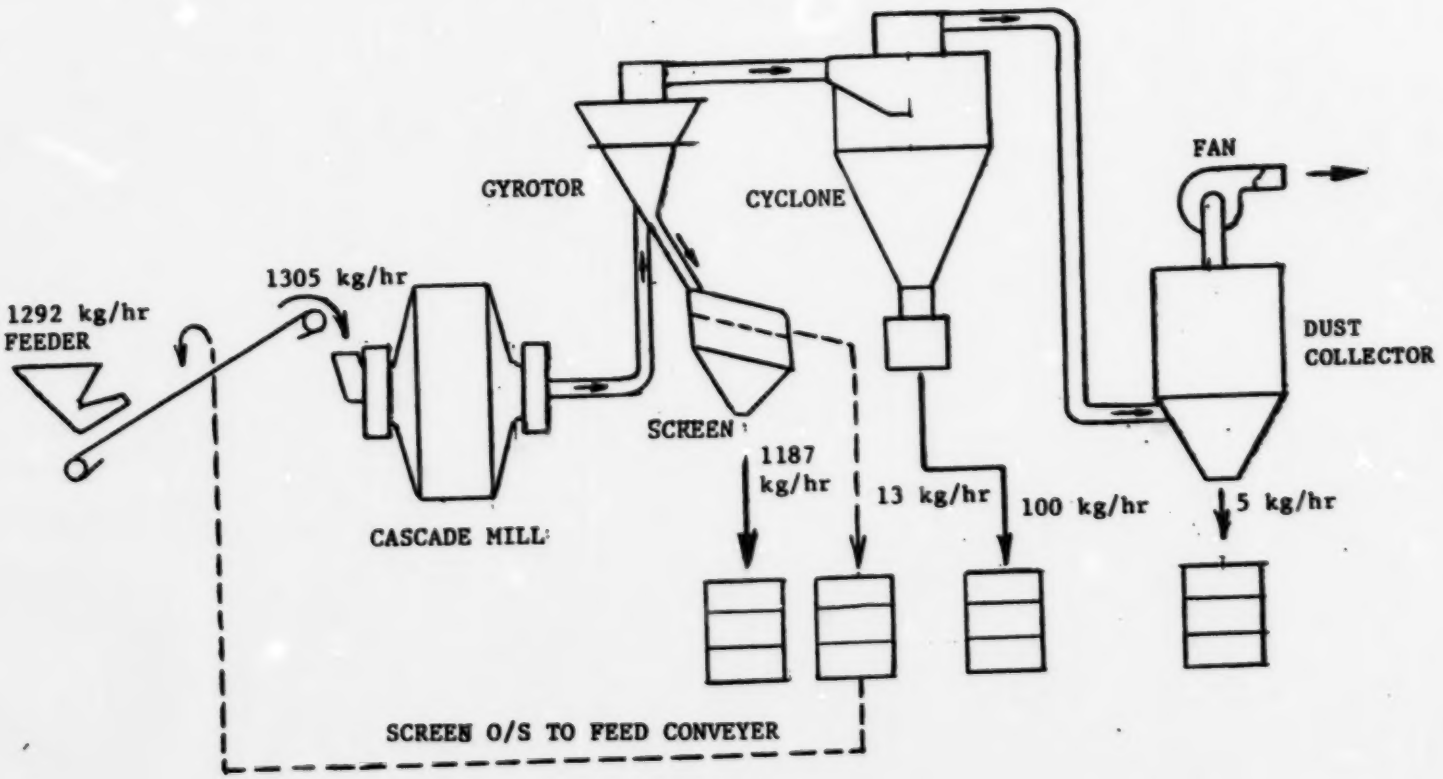
PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS

MILLING OF SILICA ORE

CIRCUIT CONFIGURATION

RUN No. 10



WDI

5.4.7 Run. No. 11

Purpose:- The purpose of this test was to run the mill fully autogenous, air swept to produce a minus 20 mesh plus 65 mesh product from the Steep Rock Quartzite. The Gyrotor oversize was screened at 20 mesh to recycle oversize material.

Description: This test was started with a fully loaded mill and ran for 2 hours 6 minutes with no technical difficulty. The gyrotor oversize material was screened at 20 mesh with the screen oversize returned to the mill for further grinding. The circulating load, both in this test and in Run No. 9, was less than 5%. The mill was dumped after this test.

Classification: Primary: Hardinge Gyrotor Air Classifier operating at 228 rpm.

Secondary: 610mm x 1220mm Dillon Vibrating Screen with a 20 mesh single deck screen.

The summary of results is presented in Table 5.4.7-T1.

The size distribution for screen undersize (product) is presented in Table 5.4.7-T2.

The size distribution for screen oversize is presented in Table 5.4.7-T3.

The size distribution curves are shown in Figures 5.4.7-F1 and Figure 5.4.7 - F2

The mass balance flow diagram is presented in Figure 5.4.7-F3.

The mill load size distribution is presented in Table 5.4.7-T4 and Figure 5.4.7-F4.

Table 5.4.7-T1

SUMMARY OF TEST RESULTS

Run. No. 11

TYPE OF RUN	Dry, Fully Autogenous
% MOISTURE	2%
DRY FEED TO MILL	2941 kg
OPERATING TIME	2 hours, 8 minutes
AVERAGE PRODUCT RATE	1276 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	340 microns
CIRCULATING LOAD	4.4%

NO LOAD POWER DRAW	4.61 kWh
AVERAGE POWER DRAW	10.0 kWh
AVERAGE POWER AT MILL SHELL	4.52 kWh
NET MILL POWER CONSUMPTION	3.27 kWh/tonne feed
FAN AVERAGE POWER DRAW	10.0 kWh
FAN AVERAGE POWER NET	8.6 kWh
NET POWER CONSUMPTION	10.28 kWh/tonne product
	9.5 kWh/tonne feed
WORK INDEX (TONNE)	6.4

STATIC PRESSURES

MILL	117mm W.G.
GYROTOR	41mm W.G.
CYCLONE	43mm W.G.
DUST COLLECTOR	185mm W.G.
FAN	515mm W.G.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 11
DATE: FEB 13,1987

PRIMARY SCREEN UNDERSIZE

MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	0.00	0.00	0.00	100.00
10	1.7	0.00	0.00	0.00	100.00
14	1.2	0.00	0.00	0.00	100.00
20	.833	.20	.04	.04	99.96
28	.589	2.80	.60	.64	99.36
35	.420	6.90	1.47	2.11	97.89
48	.295	160.80	34.20	36.30	63.70
65	.208	119.90	25.50	61.80	38.20
100	.147	98.70	20.99	82.79	17.21
150	.105	36.50	7.76	90.56	9.44
200	.074	25.20	5.36	95.92	4.08
-200		19.20	4.08	100.00	0.00
TOTAL		470.20	100.00		

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 11
DATE: FEB 13,1987

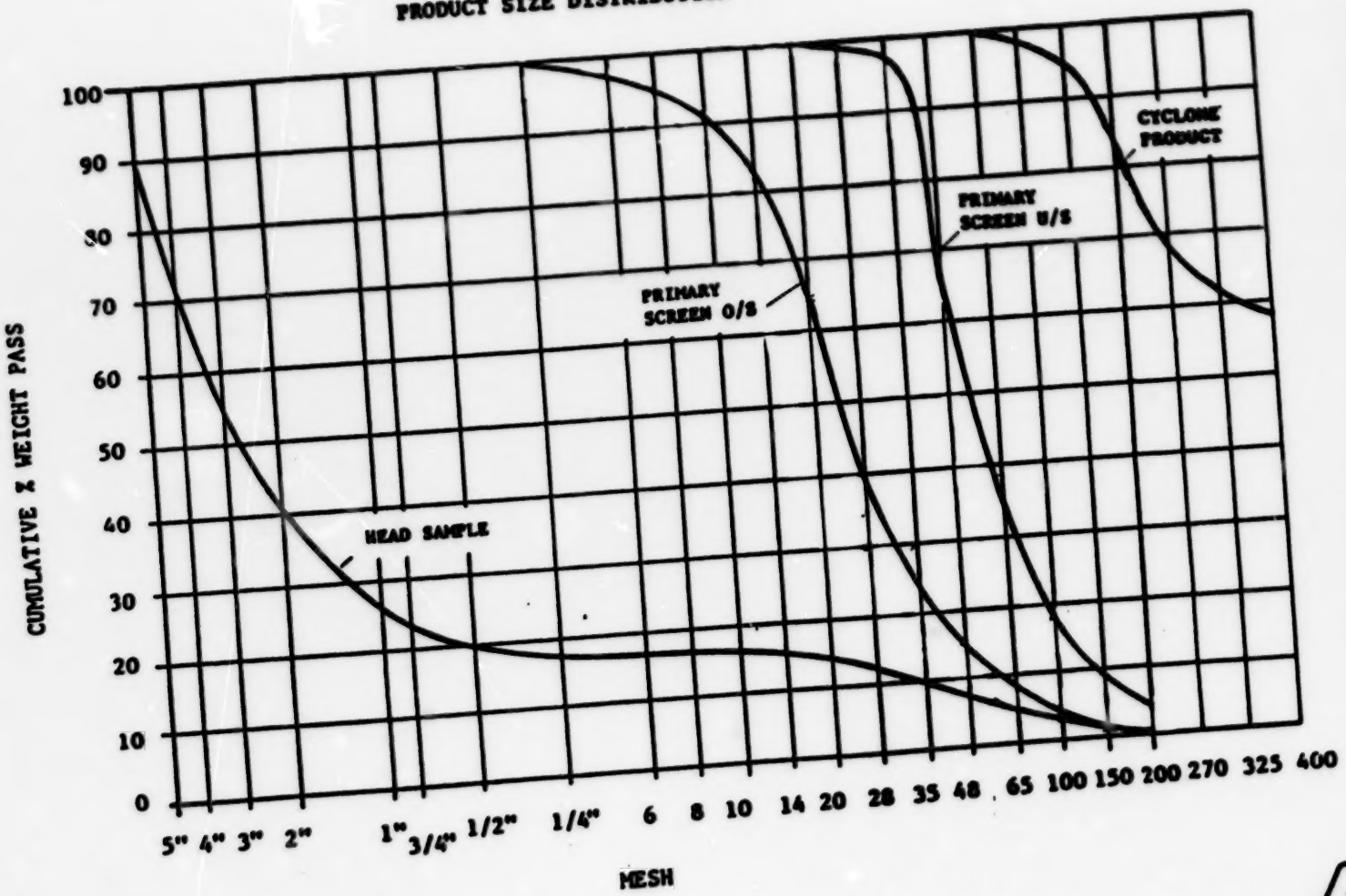
PRIMARY SCREEN OVERSIZE

MESH (NO.)	MESH (MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	21.30	2.95	2.95	97.05
8	2.4	12.70	1.76	4.71	95.29
10	1.7	25.30	3.50	8.21	91.79
14	1.2	64.40	8.91	17.12	82.88
20	.833	129.80	17.96	35.08	64.92
28	.589	221.50	30.65	65.73	34.27
35	.420	34.00	4.71	70.44	29.56
48	.295	101.80	14.09	84.53	15.47
65	.208	42.70	5.91	90.44	9.56
100	.147	36.10	5.00	95.43	4.57
150	.105	14.10	1.95	97.38	2.62
200	.074	9.20	1.27	98.66	1.34
-200		9.70	1.34	100.00	0.00
TOTAL		722.60	100.00		

DSS - CANADA CEMENT LAFARGE

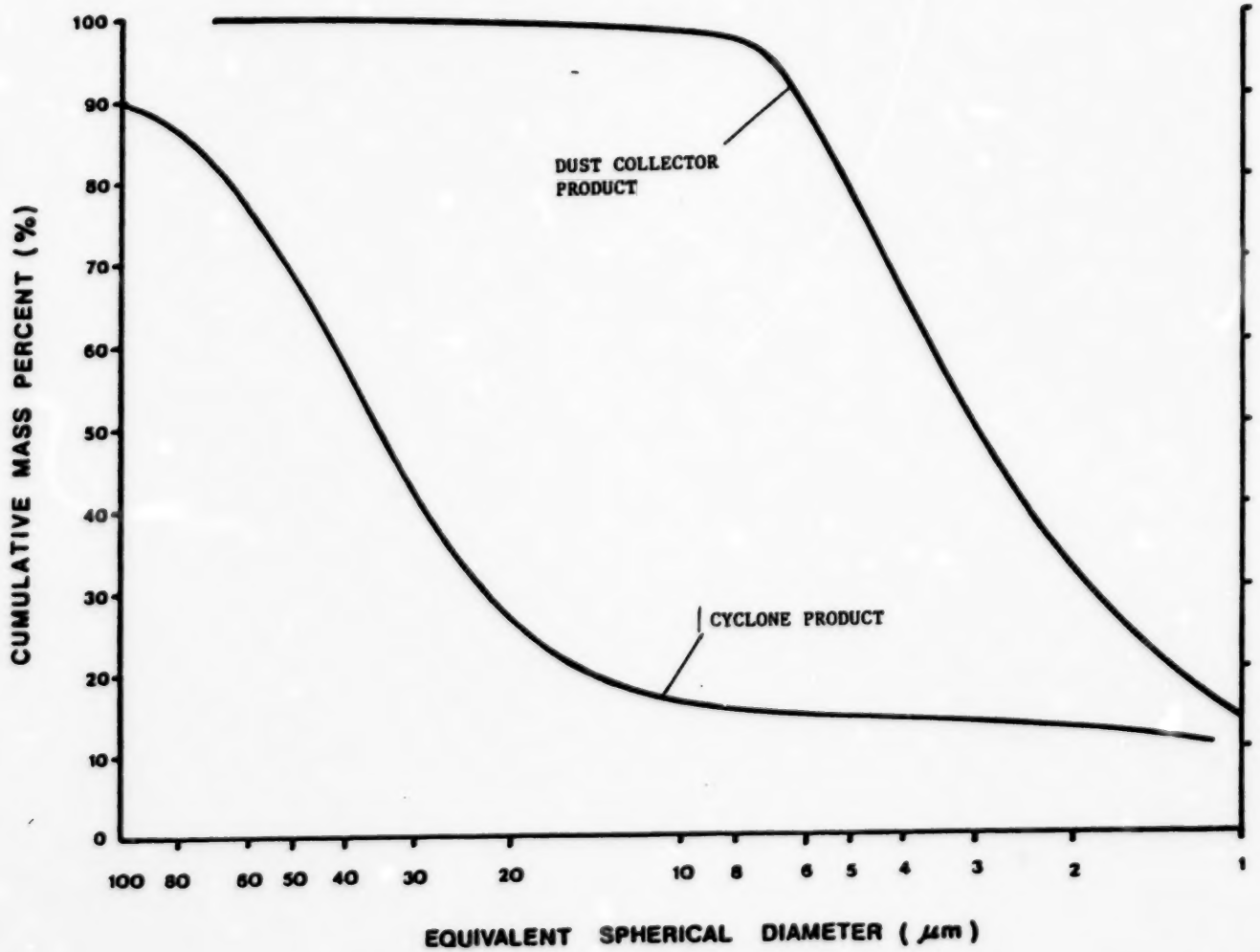
AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.11

PRODUCT SIZE DISTRIBUTION



WDI

D.S.S.- CANADA CEMENT LAFARGE LTD.
SEMI-AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 RUN No.11



DSS-CANADA CEMENT LAFARGE

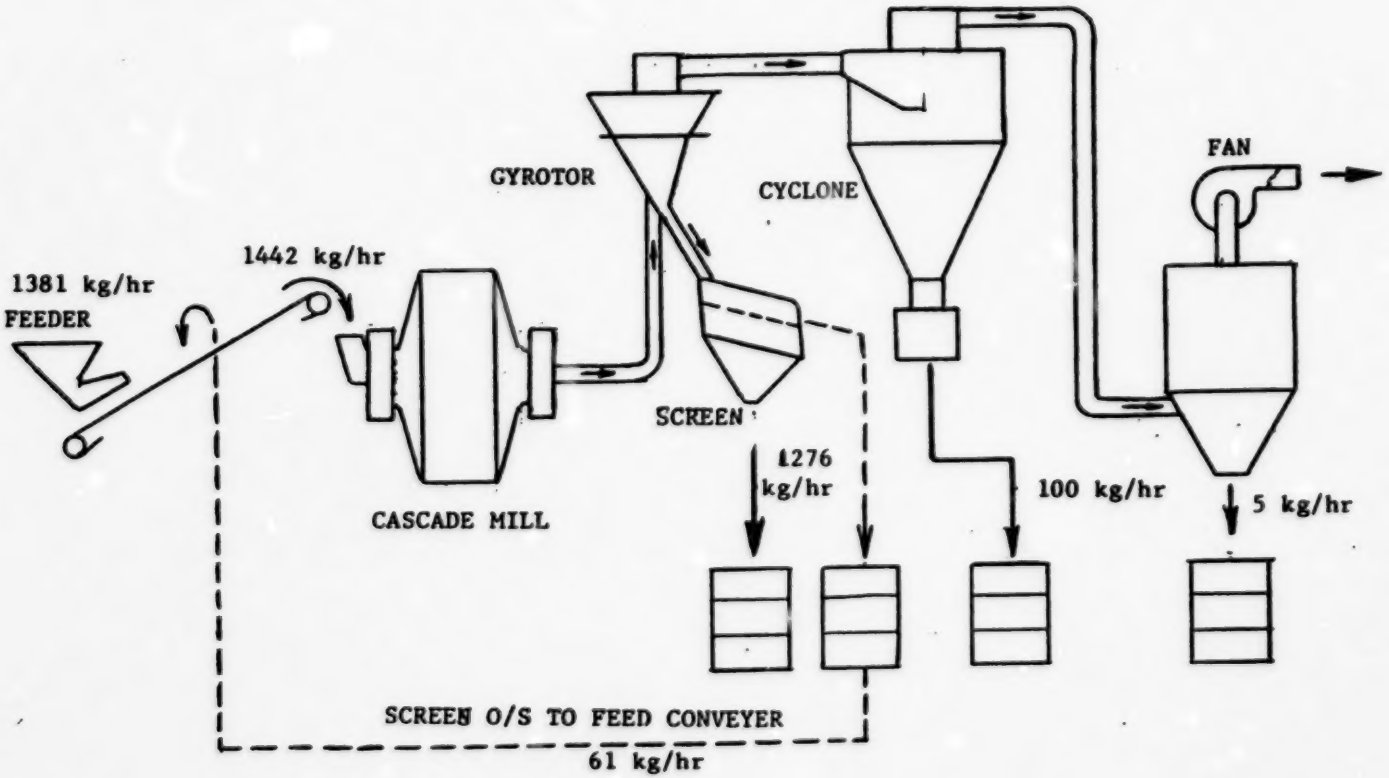
PROJECT 5174 ACTIVITY 6

AIR SWEPT AUTOGENOUS

MILLING OF SILICA ORE

CIRCUIT CONFIGURATION

RUN No. 11



S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 11
DATE: FEB 13,1987

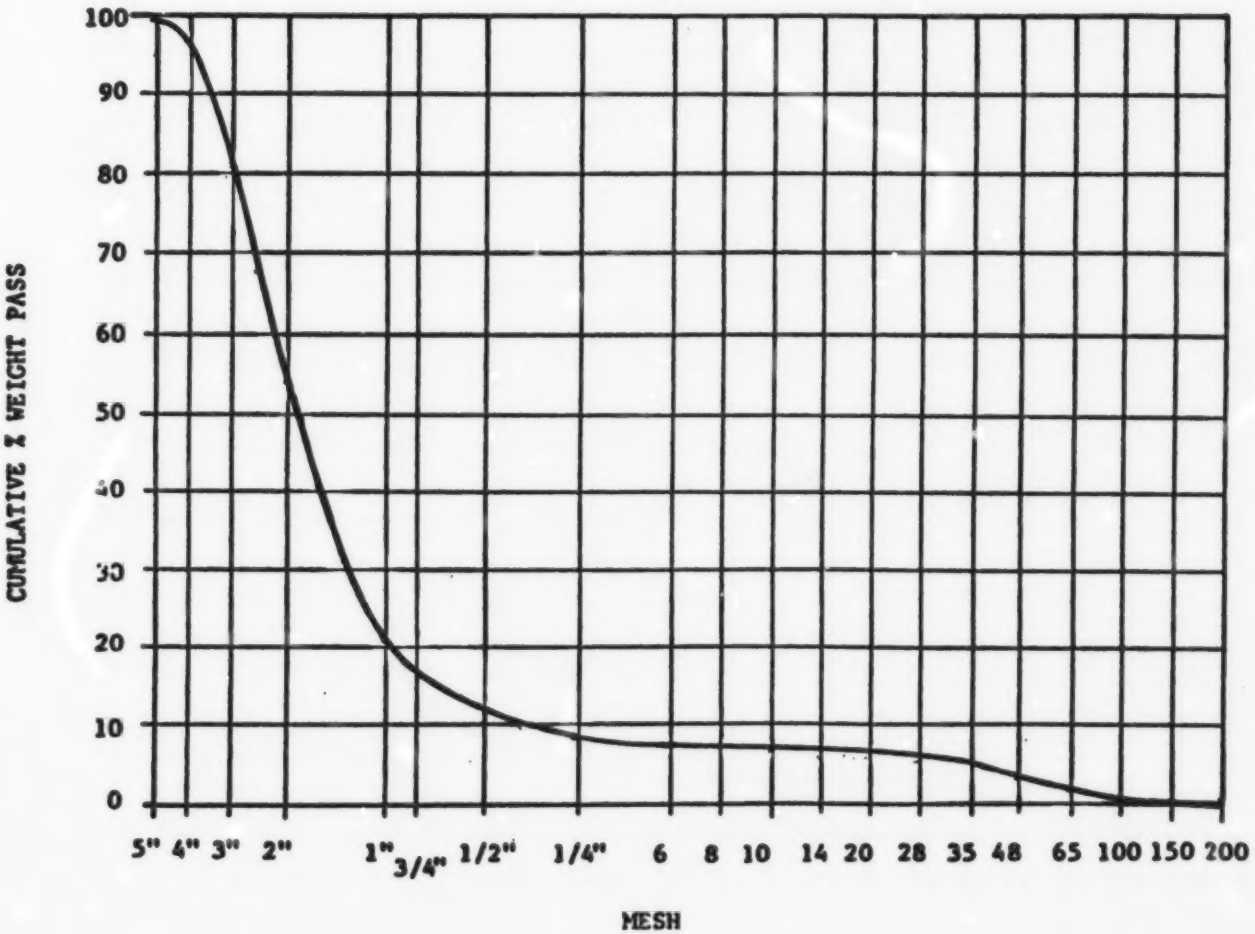
MILL LOAD

MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	8.00	.63	.63	99.37
4"	101	22.00	1.74	2.38	97.62
3"	76	208.00	16.48	18.86	81.14
2"	50.8	349.00	27.65	46.51	53.49
1"	26.7	407.00	32.25	78.76	21.24
3/4"	19.7	0.00	0.00	78.76	21.24
1/2"	12.6	98.00	7.77	86.53	13.47
1/4"	6.4	65.00	5.15	91.68	8.32
6	3.3	13.20	1.05	92.73	7.27
8	2.4	4.44	.35	93.08	6.92
10	1.7	3.17	.25	93.33	6.67
14	1.2	2.52	.20	93.53	6.47
20	.833	2.42	.19	93.72	6.28
28	.589	4.32	.34	94.06	5.94
35	.420	4.34	.34	94.41	5.59
48	.295	34.27	2.72	97.12	2.88
65	.208	18.46	1.46	98.58	1.42
100	.147	9.81	.78	99.36	.64
150	.105	2.25	.18	99.54	.46
200	.074	2.79	.22	99.76	.24
-200		3.01	.24	100.00	0.00
TOTAL		1262.00	100.00		

DSS - CANADA CEMENT LAFARGE

5.4.7-F4

AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 MILL LOAD RUN No.11



WD1

5.5 Dry Semi-Autogenous Milling Results

5.5.1 Run No. 12

Purpose: The purpose of this test was to run the mill semi-autogenous, air swept, to produce a 100% minus 20 mesh plus 65 mesh material from the Steep Rock quartzite.

Description: A 4% by volume charge of 102mm and 76mm balls were added to the mill. Apart from the ball charge, the circuit configuration remained unchanged from Test 11. It was evident throughout the test that the capacity of the fan to clear the material away from the mill was severely taxed. Constant build-up of the material at the mill discharge resulted in fluctuating flow rates and pressure drops.

Classification: Hardinge Gyrotor air classifier operating at 228 rpm. 610mm x 1220mm Dillon screen with a 20 mesh single deck screen.
The summary of results is presented in Table 5.5.1-T1.
The size distribution for the screen undersize is presented in Table 5.5.1-T2.
The size distribution for the screen oversize is presented in Table 5.5.1-T3.
The size distribution curves are presented in Figure 5.5.1-F1,F2.
The mass balance flow diagram is presented in Figure 5.5.1-F3.

Table 5.5.1-T1

SUMMARY OF TEST RESULTS

Run. No. 12

TYPE OF RUN	Dry, Semi-Autogenous
% MOISTURE	2%
DRY FEED TO MILL	4000 kg
OPERATING TIME	2 hours, 9 minutes
AVERAGE PRODUCT RATE	1791 kg/hour
HEAD F 80	101,000 microns
PRODUCT P 80	390 microns
CIRCULATING LOAD	7.1%

NO LOAD POWER DRAW	4.61 kWh
AVERAGE POWER DRAW	12.09 kWh
AVERAGE POWER AT MILL SHELL	6.28 kWh
NET MILL POWER CONSUMPTION	3.37 kWh/tonne feed
FAN AVERAGE POWER DRAW	9.06 kWh
FAN AVERAGE POWER NET	7.80 kWh
NET POWER CONSUMPTION	7.86 kWh/tonne product
	7.55 kWh/tonne feed
WORK INDEX (TONNE)	7.1

STATIC PRESSURES

MILL	282mm W.G.
GYROTOR	112mm W.G.
CYCLONE	23mm W.G.
DUST COLLECTOR	160mm W.G.
FAN	515mm W.G.

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 12
DATE: FEB 19, 1987

PRIMARY SCREEN UNDERSIZE

MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	0.00	0.00	0.00	100.00
8	2.4	0.00	0.00	0.00	100.00
10	1.7	0.00	0.00	0.00	100.00
14	1.2	0.00	0.00	0.00	100.00
20	.833	1.50	.25	.25	99.75
28	.589	6.90	1.15	1.41	98.59
35	.420	66.00	11.05	12.45	87.55
48	.295	262.90	44.00	56.45	43.55
65	.208	64.40	10.78	67.23	32.77
100	.147	108.00	18.08	85.31	14.69
150	.105	36.20	6.06	91.36	8.64
200	.074	32.00	5.36	96.72	3.28
-200		19.60	3.28	100.00	0.00
TOTAL		597.50	100.00		

S I Z E D I S T R I B U T I O N

DSS-CCL
AUTOGENOUS MILLING OF SILICA ORE
PROJECT NO. 5174 ACTIVTY 6

RUN NO. 12
DATE: FEB 19, 1987

PRIMARY SCREEN OVERSIZE

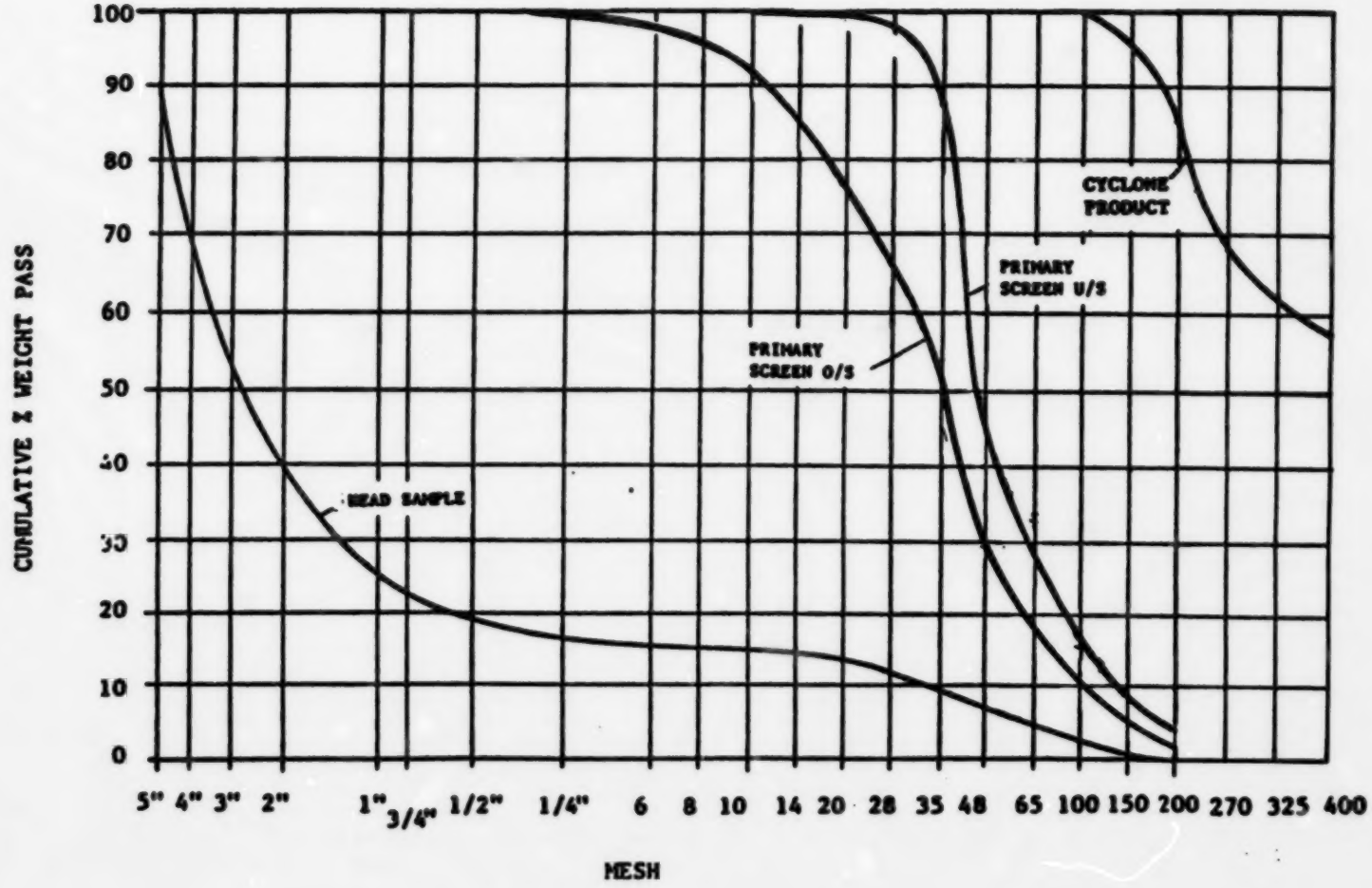
MESH (NO.)	(MM)	WEIGHT (GRAMS)	WEIGHT %	CUM. % RETAINED	CUM. % PASSING
5"	127	0.00	0.00	0.00	100.00
4"	101	0.00	0.00	0.00	100.00
3"	76	0.00	0.00	0.00	100.00
2"	50.8	0.00	0.00	0.00	100.00
1"	26.7	0.00	0.00	0.00	100.00
3/4"	19.7	0.00	0.00	0.00	100.00
1/2"	12.6	0.00	0.00	0.00	100.00
1/4"	6.4	0.00	0.00	0.00	100.00
6	3.3	16.30	2.61	2.61	97.39
8	2.4	11.60	1.86	4.46	95.54
10	1.7	24.20	3.87	8.34	91.66
14	1.2	38.20	6.11	14.45	85.55
20	.833	56.40	9.02	23.47	76.53
28	.589	62.30	9.97	33.44	66.56
35	.420	81.10	12.98	46.42	53.58
48	.295	150.60	24.10	70.51	29.49
65	.208	61.70	9.87	80.38	19.62
100	.147	64.20	10.27	90.66	9.34
150	.105	24.20	3.87	94.53	5.47
200	.074	17.10	2.74	97.26	2.74
-200		17.10	2.74	100.00	0.00
TOTAL		625.00	100.00		

DSS - CANADA CEMENT LAFARGE

5.5.1-F1

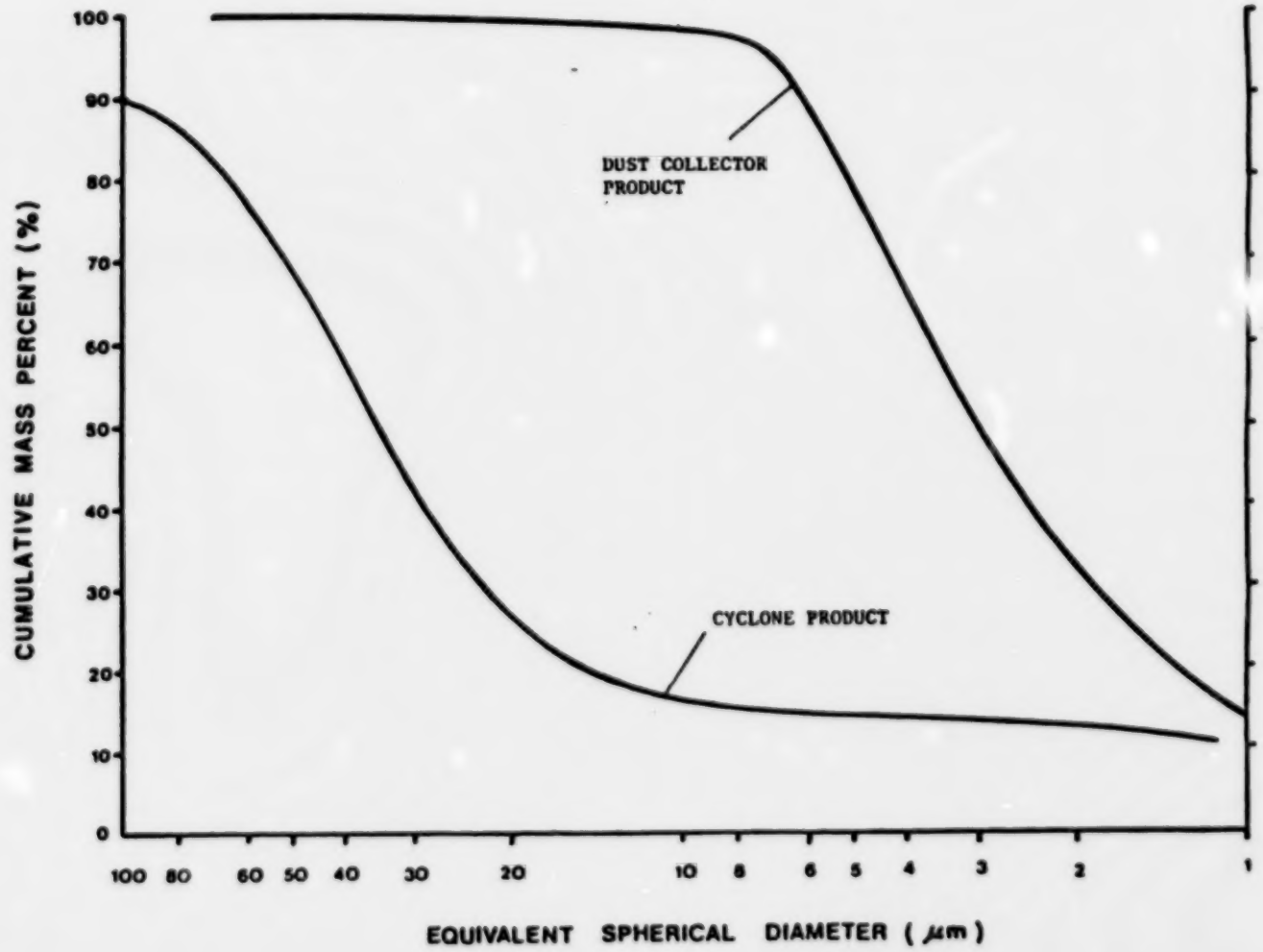
SEMI-AUTOGENOUS MILLING OF SILICA ORE
PROJECT No.5174 RUN No.12

PRODUCT SIZE DISTRIBUTION



WDI

D.S.S.- CANADA CEMENT LAFARGE LTD.
AUTOGENOUS GRINDING
PARTICLE SIZE DISTRIBUTION
ACTIVITY 6 RUN No. 12



DSS-CANADA CEMENT LAFARGE

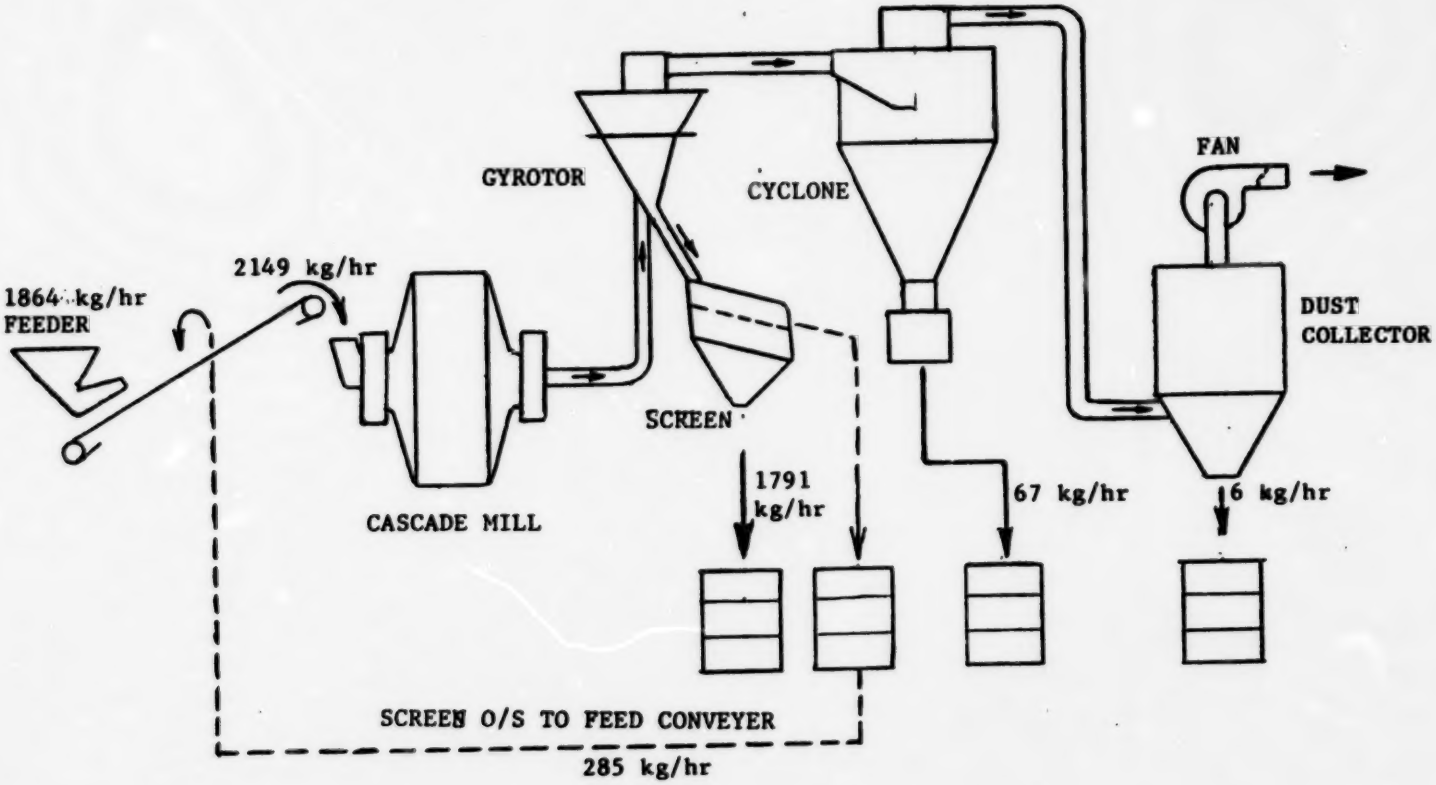
PROJECT 5174 ACTIVITY 6

AIR SWEPT SEMI-AUTOGENOUS

MILLING OF SILICA ORE

CIRCUIT CONFIGURATION

RUN No. 12



6.0 CONCLUSIONS

- Pilot plant testwork completed by Witteck Development on a Steep Rock Resources Quartzite material indicated that a minus 20 plus 65 mesh course sand grade product could be produced by wet or dry autogenous grinding.

- The silica ore used for the grinding tests was amenable to wet and dry autogenous grinding as shown by the low recirculating loads on the grinding mill and the yield of final product of minus 65 mesh material present in the mill discharge.

- Dry autogenous grinding produced a coarse product and a higher product yield than wet autogenous grinding. This was an indication that classification was taking place in the mill. Particles in the minus 20 plus 65 mesh size range were being removed from the mill as soon as they were generated, thus not being ground further.

- Based on grinding mill energy requirements only, and new feed to the circuit, dry autogenous grinding required 37% less energy compared to wet autogenous grinding (3.3 kWh/tonne vs 5.3 kWh/tonne of new feed). However, using tonnes of final silica sand grade product as the measure of efficiency, dry autogenous grinding required 60% less energy than wet autogenous grinding (5.2 kWh/tonne vs 12.9 kWh/tonne product).

- Based on total grinding system energy requirements, including energy for the dry classification system and new feed to the circuit, wet autogenous grinding required 43% less energy than dry autogenous grinding (5.3 kWh/tonne vs 9.6 kWh/tonne of new feed). This is based on the results of the most comparable wet and dry grinding test runs. However, using tonnes of silica sand grade product as the

measure of efficiency, wet autogenous grinding required 13% less energy than dry autogenous grinding (12.9 kWh/tonne vs 14.9 kWh/tonne of final product). A portion of this energy saving would be used for classifying the wet autogenous mill discharge.

- The energy consumption during grinding for dry semi-autogenous grinding and dry autogenous grinding were similar based on per tonne of material treated. However, the comparison changes when energy for classification is included. Using total circuit energy data, dry semi-autogenous grinding shows a 22% saving in energy consumption per tonne of ore treated when compared with fully autogenous grinding (7.6 kWh/tonne vs 9.6 kWh/tonne). The relative saving is the same when energy consumptions are expressed on a per tonne of sand grade product basis (11.7 kWh/tonne vs 14.9 kWh/tonne).

- The production of minus 65 mesh material in the mill discharge suggested that classification taking place in the mill could be improved. It was observed during the test program that the fan was heavily loaded in removing the material from the mill.

- Increased fan capacity may have improved the product quality by removing the properly sized particles as soon as they were generated from the mill and reducing the amount of overgrinding taking place.

- The build-up of 25mm and 50mm material in the mill during the autogenous grinding testing indicated that the addition of steel grinding media for dry semi-autogenous grinding may have been beneficial. This was confirmed by a grinding test in which the use of dry semi-autogenous grinding increased throughput by 40% with a corresponding 20% decrease in power consumption compared to dry autogenous grinding.

- The wet autogenous grinding tests were carried out with a mill density of 65 to 70% solids. A decrease in the mill density may have reduced the amount of overgrinding that occurred during these tests.

- Dry semi-autogenous grinding showed the lowest energy consumption for the production per tonne of minus 20 plus 65 mesh coarse silica product.

- Further testwork is required to optimize the grinding conditions required to maximize the product yield and minimize power consumption required to grind silica ore. Wet semi-autogenous grinding should be considered for the production of silica sand.

- Chemical analysis of the feed and products indicated there was no concentration of deleterious substances in the product caused by the grinding system.

APPENDIX I

GLOSSARY OF TERMS

No Load Power Draw	-	Total power required to operate empty mill and drive
Average Power Draw	-	Total power required to operate fully charged mill and drive
Average Power at Mill Shell	-	Average power draw less no load power draw, less drive losses, i.e. power available to grind ore
Net Mill Power Consumption	-	Average power at mill shell per tonne of final product
Fan Average Power Draw	-	Total power required to operate fan and drive.
Fan Net Power	-	Total power required to operate fan less drive
Net Power Consumption	-	Net fan power plus average power at mill shell, per tonne of final product.
Work Index	-	Empirical work index for single stage wet, fully autogenous milling, calculated using the formula below.
Work Index	-	Empirical work index for single stage, dry, fully autogenous milling calculated from the following formula.

$$Wi = \frac{W}{10\left[\sqrt{\frac{1}{P_{80}}} - \sqrt{\frac{1}{F_{80}}}\right]}$$

P_{80} = 80% passing size in product
F_{80} = 80% passing size in feed
Wi = Work Index
W = Net power consumption in kilowatt hours per tonne

WD1

APPENDIX II

Industrial Hygiene Survey to Evaluate Exposure to Alpha Quartz Silica

CSC J1076

Prepared for
Witteck Development

Prepared by
R. Tsugios-Sowa, B.Sc., M.H.Sc.

March, 1987

Concord Scientific Corporation

EXECUTIVE SUMMARY

At the request of Witteck Development, Mississauga, an industrial hygiene survey was undertaken to assess airborne exposures to alpha quartz silica during milling operations. Sample collections were conducted on January 30, 1987; collection and analysis were performed in accordance with the Ontario Ministry of Labour's Regulation respecting Silica (Ontario Regulation 769/83), made under the Occupational Health and Safety Act, 1979.

Sampling and analysis for alpha quartz silica revealed that the Ministry of Labour's exposure criteria for silica was exceeded for all employees evaluated.

Recommendations regarding the implementation of control procedures to reduce employee exposures have been made.

1.0 INTRODUCTION

The inhalation of free crystalline silica over an extended period of time may result in silicosis, a condition in which fibrous tissue is deposited in the lungs. Such deposition eventually results in the production of rigid nodules, which decreases the lung's ability to expand. Silicosis symptoms are progressive with continued exposure, increasing age and continued smoking habits. Symptoms of the disease include shortness of breath, coughing and chest pain.

The Ontario Ministry of Labour has designated silica under the Regulation respecting Silica in 1983. The industrial hygiene evaluation conducted by Concord Scientific Corporation was undertaken in accordance with this Regulation to establish concentrations in the mill area. In the Regulation, the employer is required to take all necessary measures and procedures (such as engineering controls, work and hygiene practices) to ensure that the time-weighted average exposure of a worker to airborne silica to a level equal to or less than a time-weighted average of 0.1 milligrams of silica per cubic metre of air. A time-weighted average implies that the values may be in excess of this value at a given instant, however, the sum of the values averaged over an eight-hour day, forty-hour work week must be less than or equal to 0.1 mg/m^3 of free crystalline (alpha quartz) silica.

In addition to the Regulation respecting Silica, a Regulation respecting Silica for construction projects and aggregate production was proposed by the Ministry of Labour in September, 1985. Upon adoption, this regulation would apply to constructors carrying out projects. This proposal defines classifications of work, respiratory protective equipment and controls for each type of operation.

Although the regulated level of silica is 0.10 mg/m^3 (in the Regulation respecting silica) it is the practice of Concord Scientific to recommend exposures which are one-tenth of those which are regulated.

2.0 SAMPLING STRATEGY

Five personal samples were collected on January 30, 1987 for analysis of respirable alpha quartz silica and respirable dust. Personal samples to establish in-plant concentrations in the mill area were taken during a grinding operation and were thought to be representative of an average work day during this particular project.

One area sample was collected on January 30, 1987 for analysis of total suspended particulates. The sample was collected at the junction of the hallway and laboratory to establish the quantity of dust which was being circulated from the mill to other areas within the building.

2.1 Sampling Method and Analysis

All samples were collected by battery-operated personal sampling pumps. To collect respirable silica and dust, air was drawn through a nylon cyclone and pre-weighed silver membrane filter at a flow rate of 1.7 litres of air per minute. The silver membrane filter and support pad were contained in a three-stage cassette and samples were collected from the workers' breathing zone. Analysis of cassettes was performed using x-ray diffraction. Sample collection and analysis were conducted in accordance with the Ministry of Labour Regulation respecting Silica (Ontario Regulation 769/83).

To collect suspended particulates, air was drawn through a pre-weighed teflon filter at a flow rate of 2 litres of air per minute. The teflon filter and support pad were contained in a two-stage cassette. The sample was collected approximately four feet from the ground. Analysis of the filter was performed gravimetrically.

3.0 RESULTS

Concentrations of respirable alpha quartz and respirable dust are presented in Table 1 and are expressed as milligrams of contaminant per cubic metre of air (mg/m^3). In accordance with Section 12 of the Regulation respecting Silica, the results of airborne silica concentrations and worker exposure must be:

- posted by the employer in a conspicuous place for a period of at least fourteen days;
- furnished to the joint health and safety committee; and
- kept by the employer for a period of at least five years.

TABLE 1

Results of Air Sampling
January 30, 1987
Witteck Development Inc.

Sample Number	Employee Location	Duration of Sample (minutes)	Respirable Silica* (mg/m^3)	Respirable Dust (mg/m^3)
86-1714	H. Jones feeder and control panel operator	1011-1229 (138) 1255-1457 (122)	.11	.26
86-1720	P. Bouma feeder	0943-1010 (27)	.42	1.47
86-1725	N. Sewaid pusher at top of mill	0909-1259 (230) 1344-1457 (73)	.17	.30
86-1726	R. Brisebois bobcat operator	0905-1410 (245) 1449-1454 (5)	.43	.64
86-1727	D. Purdie project engineer	0935-1140 (125) 1435-1458 (143)	.42	.68
1	area sample engineering lab and hallway	0947-1509 (322)	total dust+	2.3 mg/m^3

*Ministry of Labour Regulation Respecting Silica stipulates a time-weighted average concentration of 0.10 mg silica per m^3 of air and must not exceed 0.20 mg silica/m^3 at any time.

+Ministry of Labour Regulation respecting Control of Exposure to Biological or Chemical Agents (O. Reg. 654/86) stipulates a time-weighted average concentration of 10 mg/m^3 of nuisance dust.

4.0 DISCUSSION

Exposures to alpha quartz silica based on personal samples collected during the milling operation January 30, 1987 indicate that all employee exposures are in excess of the Ministry of Labour's time-weighted average exposure criteria of 0.10 mg/m^3. Exposures during the milling operation indicate that levels ranged from 0.11 mg/m^3 to 0.43 mg/m^3.

At present, Witteck Development requires that employees entering the mill area wear half-face cartridge respirators (Willson 1700). Under the Code for Respiratory Equipment for Silica (Ontario Regulation 769/83) this type of respirator provides adequate protection against silica exposures of less than or equal to 0.5 mg/m^3. These respirators would be considered satisfactory for the concentrations found on January 30, 1987.

Although respirators are currently in use by mill area employees under Section 5 (i) of the Regulation, the use of respiratory equipment should be restricted to situations where:

- an emergency exists;
- procedures to control workers' exposures:
  - do not exist or are unavailable;
  - are impractical for the length of time and frequency of exposure; and
  - are ineffective due to a breakdown in equipment.

In the proposed regulation, dust generation should be controlled by the use of dust collection systems, wetting or positive pressure enclosures equipped with air filtered by high efficiency particulate aerosol filters. Where these controls are unreasonable or impractical, respirators should be provided and used.

The implementation of engineering controls and work practices are preferred methods of controlling exposures in contrast to mandatory respirator use, especially in light of the fact that Witteck may undertake other projects involving the use of silica-containing sands.

The exposure levels found on January 30, 1987 indicate that procedures to control silica exposures should be implemented. A silica control program (section 7 of the Regulation respecting Silica) includes: engineering controls, work and hygiene practices; employee exposure monitoring; medical examinations and clinical tests; exposure record maintenance; and a training program. The proposed regulation requires that all workers are trained with respect to work practice and procedure and are to undergo medical examinations and clinical tests.

A number of practices may be implemented to reduce employee exposures. For example, to prevent the re-entrainment of silica-containing sands, regular clean-up and removal procedures in the mill should be implemented. At present, no such procedure exists. Sand which falls from the tow motor shovel and collection

barrels should be collected as soon as possible during the shift and upon completion of the shift. This procedure is found in section 6(3) of the proposed regulation. To prevent the loss of sand from the shovel during transport from storage, a hinged lid covering the shovel may be used to contain the sand.

The results of the sample collected at the hallway and laboratory junction indicated that sand is transported from the mill to other areas within the building. Sand is visible on the stairs and hallway connecting the office and mill areas. The movement of employees from the office area to the sample preparation room (accessible only through the mill) and from the mill to the lunch and washrooms causes the movement of sand throughout the building.

The implementation of a dust collection system (such as a locally exhausted hood) placed at the site of barrel collection will decrease the exposure of the employee responsible for filling and changing the barrels. Such a system may be connected to the cyclone and baghouse.